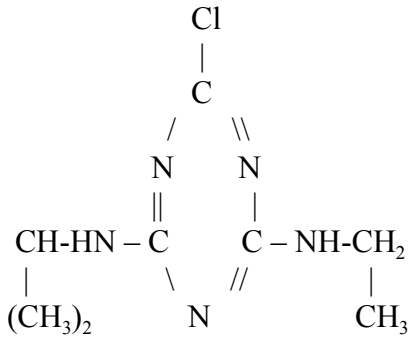
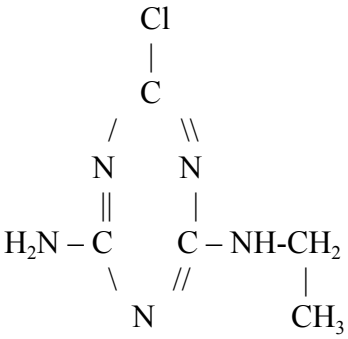
Appendix I. Diagram/Structure of Atrazine and Major Degradates and Metabolites

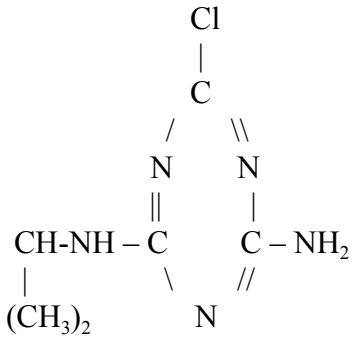


Atrazine

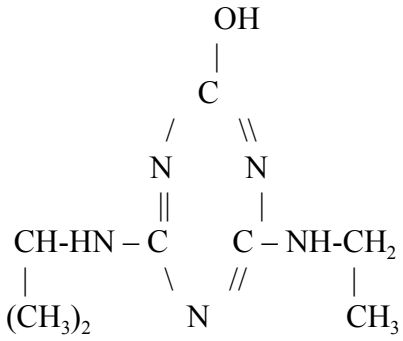
Atrazine Soil Degradates:



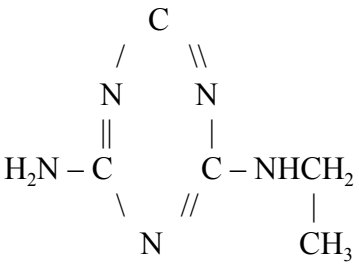
Deisopropylatrazine
(G-28279)



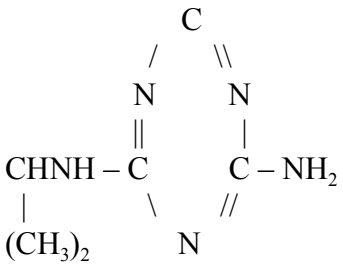
Deethylatrazine
(G-30033)



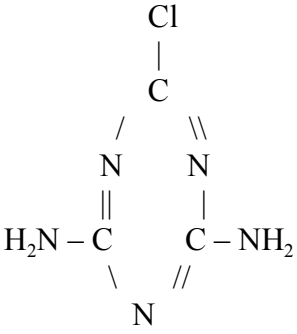
Hydroxyatrazine
(G-34048)



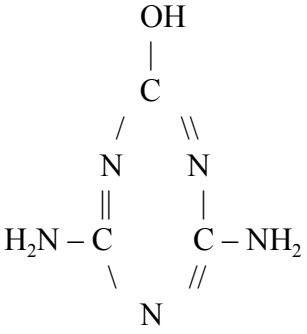
Deisopropylhydroxyatrazine
(GS-17792)



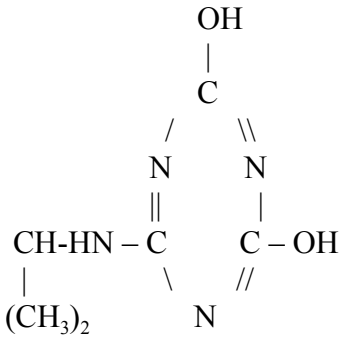
Deethylhydroxyatrazine
(GS-17794)



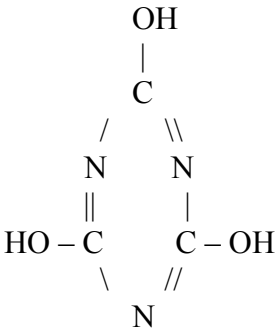
Diaminochlorotriazine
(G-28273)



Diaminohydroxyatrazine
(G-17791)

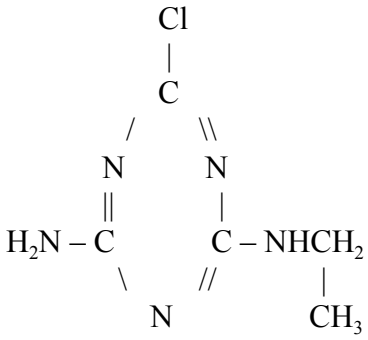


2, 4-Hydroxy-6-isopropylamino-s-triazine
(G-11957)

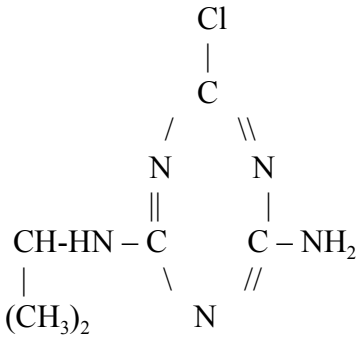


Cyanuric Acid

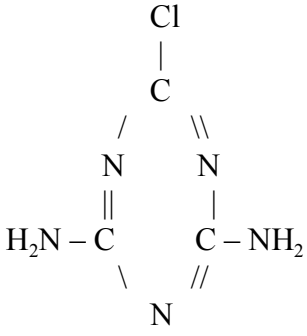
Atrazine Photodegradates (Burkhard and Guth, 1976):



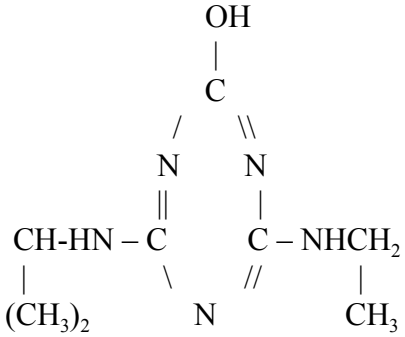
Deisopropylatrazine
(G-28279)



Deethylatrazine
(G-30033)

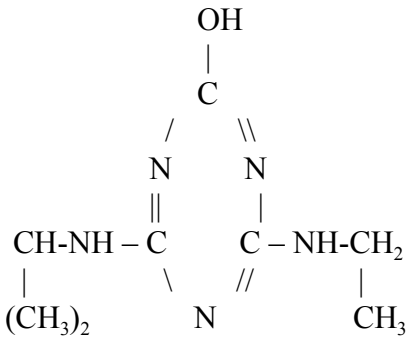


Diaminochlorotriazine
(G-28273)

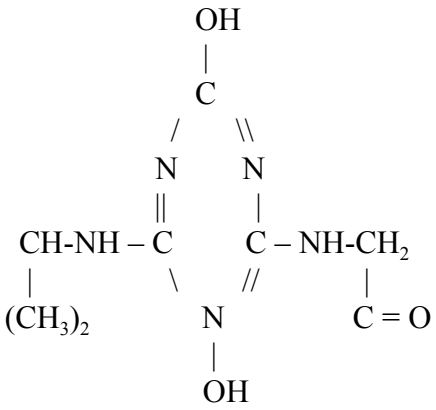


Hydroxyatrazine
(G-34048)

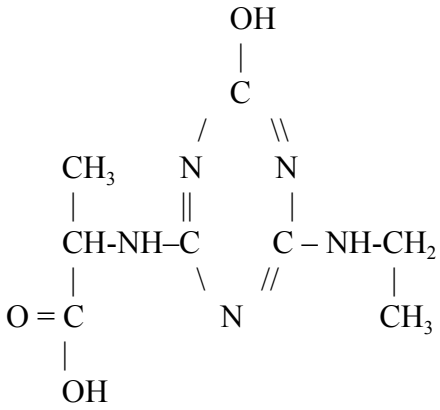
Major Mammalian Metabolites:



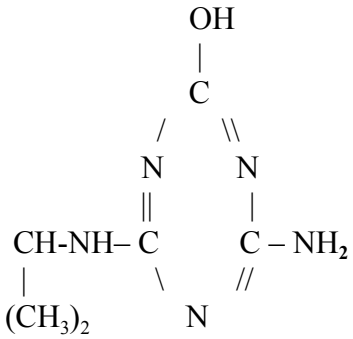
Hydroxyatrazine
(G-34048)



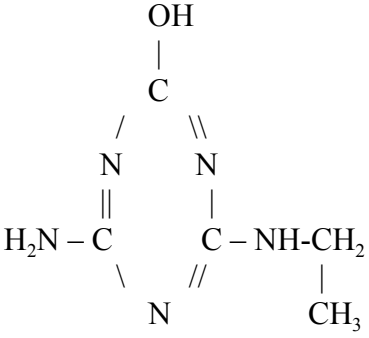
Ethanoichydroxyatrazine



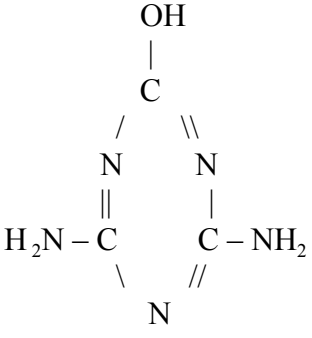
Isopropanoichydroxytriazine



Deethylhydroxyatrazine
(GS-17794)

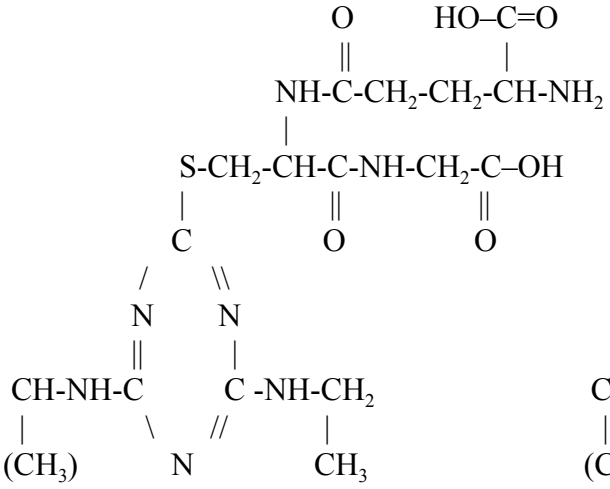


Deisopropylhydroxyatrazine
(GS-17792)

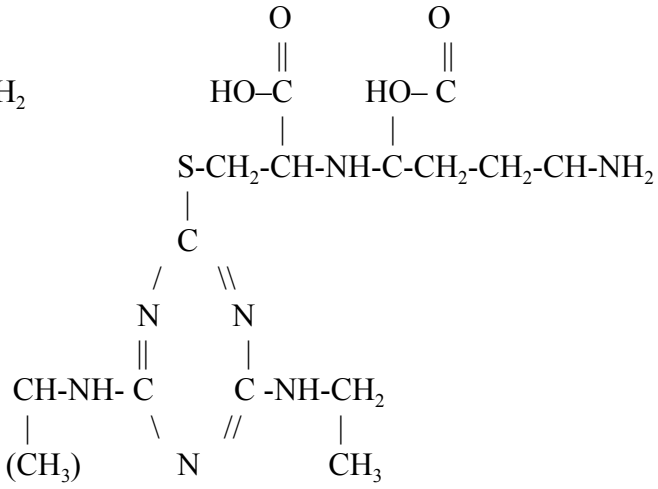


Diaminohydroxyatrazine
(GS-17791)

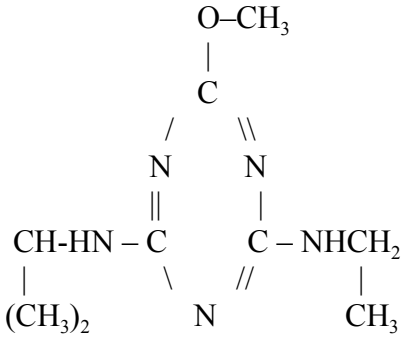
Major Plant Metabolites:



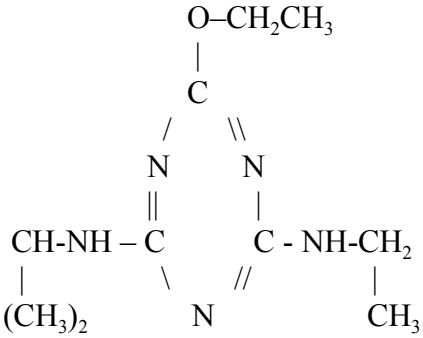
S-(4-Ethylamino-6-isopropylamino-2s-triazino) Glutathione



-L-Glutamyl-S-(4-ethylamino-6-isopropylamino-2-s-triazino)-L-Cysteine



2-Methoxy-4-ethylamino-6-isopropylamino-s-triazine



2-Ethoxy-4-ethylamino-6-isopropylamino-s-triazine

Appendix II. Environmental Fate and Transport Characterization

Each individual guideline study is discussed separately. The chemical names and structures of atrazine and its degradation products are listed in Appendix 1.

Hydrolysis (161-1)

Based on the results of the hydrolysis study (MRID 40431319), atrazine did not hydrolyze at pH 5, 7, and 9. It was concluded that hydrolysis is not an important degradation mechanism for atrazine.

Aquatic Photodegradation (161-2)

The study (MRID 00024328) showed that [^{14}C]atrazine degraded with a registrant-calculated half-life of 25 ± 2 hours in unbuffered aqueous solutions (initial pH 6.8) that were irradiated with a 125-W mercury vapor lamp at 15^{o}C; in unbuffered aqueous solutions sensitized with 1% acetone, the half-life decreased to 4.9 ± 0.5 hours.

The study (MRID 42089904) showed that in buffered solution at pH 7, atrazine did not appreciably degrade under natural sunlight conditions with a calculated half-life of approximately 335 days from a rate constant of 1.72 x 10^{-4} hours^{-1}. However, under artificial light irradiation with mercury arc lamp, atrazine degraded at a faster rate with a half-life of approximately 17 hours. Due to the lack of a comparison of the mercury arc lamp with natural sunlight, and no UV-VIS spectrum of atrazine in pH 7, the study is considered to be supplemental. For the purpose of risk assessment, the half-life result of 335 days with natural sunlight should be considered. Information is requested on the intensity of the mercury arc lamp and the US-VIS spectrum of atrazine in pH 7 for more accurate review.

Soil Photodegradation (161-3)

The study (MRID 40431320) was investigated with both natural and artificial sunlight exposures. The results with artificial sunlight showed a half-life of 5.3 days, when corrected with dark control, the half-life was 7.4 days. With natural sunlight, the half-life was determined to be 12 days.

The study (MRID 42089905) was investigated with artificial sunlight exposure. The half-life under non-irradiated conditions was 267 days, and the half-life under irradiated conditions was 38 days. The net half-life attributable to photodegradation is 45 days.

Aerobic Soil Metabolism (162-1)

The study (MRID 40431321) was considered supplemental. Based on the data of 94 days, the half-life of atrazine in loam soil was calculated as 140 days. The main metabolites detected at all sampling times were G-30033 and G-28279, but the metabolite G-34048 was not detected until days 62 and 94.

The second study (MRID 40629303) was also considered supplemental. The calculated half-life was 146 days under non-sterile aerobic conditions and to be very slow under sterile conditions. The degradates identified were G-30033, G-28279, G-28273, G-34048, GS-17794, and GS-17792.

The third study (MRID 00040663) with four Hawaiian soils was rejected due to several deficiencies: (1) no material balances, (2) soils were not completely characterized, (3) pattern formation and decline of degradates was not addressed, and (4) purity of the test substance was not reported.

For the similar deficiencies as the third study, the fourth study (MRID 40431322) with a wet Tennessee soil was also rejected.

The study (MRID 42089906) with atrazine applied on California loam soil showed an aerobic half-life of approximately 146 days. The degradates identified were G-30033, G-28279, G-28273, and G-34048.

Anaerobic Soil Metabolism (162-2)

The study (MRID 40431321) was considered supplemental. The calculated half-life for atrazine under anaerobic conditions was about 159 days. The metabolites G-30033 and G-28279 were present at all sampling times in both soil extracts and supernatant water; G-28273 and G-34048 were also present, but not at all sampling times.

The half-life value was not established in the second study (MRID 40629303). The degradates identified were G-30033, G-28279, G-28273, and G-34048.

The study (MRID 42089906) with atrazine applied on California loam soil showed that when flooded with water, atrazine degraded with a calculated half-life of approximately 159 days. The degradates identified were G-30033, G-28279, G-28273, and G-34048.

Anaerobic Aquatic Metabolism (162-3)

The study (MRID 40431323) is acceptable. The combined water/sediment (sandy clay) half-life was calculated as 608 days (330 days in sediment; 578 days in water). Production of volatile materials was minimal. Bound residues increased with time, but leveled to about 10% of applied dose by month 12. About 70% of radioactivity in water and 4% in sediment was still associated with parent atrazine after 12 months. Metabolites were present at low levels (G-30033, 4.7%; G-34048, 5%; and G-28279, 1.4%).

Mobility/Adsorption/Desorption (163-1)

Several studies (MRID 00027134, 00116620, 00044017, 00098254, and 00105942) were unacceptable due to various deficiencies. The study (MRID 40431324) was acceptable and partially contributed to fulfill data requirements for the mobility of atrazine. A batch-equilibrium adsorption/desorption was conducted with four different soils and four different concentrations of ^{14}C-label atrazine. The Kads constants ranged from 0.427 (sand) to 2.030

(loam soil). The Kdes constants ranged from 2.261 (silty loam soil) to 14.90 (sandy loam soil). Koc ranged from 55.0 (sandy loam soil) to 135 (loam soil) for the adsorption phase. These results indicated that atrazine was not strongly adsorbed onto soil particles and that desorption occurred readily.

A batch-equilibrium adsorption/desorption was conducted with four different soils and four different concentrations of ^{14}C-label G-28273 (MRID 40431327). The Kads constants ranged from 0.108 (sand) to 0.800 (silty clay loam). The Kdes constants ranged from 1.172 (silty clay loam) to 6.620 (sandy loam). Koc ranged from 11.6 (sandy loam) to 59.5 (silt loam) for the adsorption phase. These results indicated that G-28273 was not strongly adsorbed onto soil particles and that desorption occurred readily.

A batch-equilibrium adsorption/desorption was conducted with four different soils and four different concentrations of ^{14}C-label G-28279 (MRID 40431325). The Kads constants ranged from 0.225 (sand) to 1.144 (loam soil). The Kdes constants ranged from 1.784 (silty loam) to 12.479 (sand). Koc ranged from 35.1 (sandy loam) to 82.3 (silty loam) for the adsorption phase. These results indicated that G-28279 was not strongly adsorbed onto soil particles and that desorption occurred readily.

A batch-equilibrium adsorption/desorption was conducted with four different soils and four different concentrations of ^{14}C-label G-30033 (MRID 40431328). The Kads constants ranged from 0.116 (sand) to 0.963 (silty clay loam). The Kdes constants ranged from 8.104 (silty clay loam) to 12.87 (silt loam). Koc ranged from12.8 (sandy loam) to 66.5 (silty loam) for the adsorption phase. These results indicated that G-30033 was not strongly adsorbed onto soil particles and that desorption occurred readily.

A batch-equilibrium adsorption/desorption was conducted with four different soils and four different concentrations of ^{14}C-label G-34048 (MRID 40431326). The Kads constants ranged from 5.518 (sand) to 22.26 (silty clay loam). The Kdes constants ranged from 8.104 (silty clay loam) to 12.87 (silt loam). Koc ranged from 350 (sand) to 680 (silty loam) for the adsorption phase. These results indicated that G-34048 was the strongest adsorbed among the atrazine degradates.

In a series of studies (MRID 40431329 to 40431334) with soil thin-layer chromatography, only the degradate, hydroxyatrazine (G-34048), showed low mobility, others (atrazine, diaminochlorotriazine (G-28273), deisopropylatrazine (G-28279), and deethylatrazine (G-30033) showed high mobility in the soil environment.

In a series reports (MRID 41257901, 41257902, 41257904, 41257905, and 41257906), the adsorption/desorption characteristics of atrazine, hydroxyatrazine (G-34048), diamino-chlorotriazine (G-28273), deisopropylatrazine (G-282279), and deethylatrazine (G-30033) were addressed. The results are summarized in the tables below.

Sorption Coefficients of Atrazine and Its Main Degradates

Soil	Atrazine	Diaminochloro-s-triazine (G-28273)	Deisopropyl-atrazine (G-28279)	Deethyl-atrazine (G-30033)	Hydroxy-atrazine (G-34048)
Clay	2.46 (86.9)	1.56 (55.2)	2.73 (96.8)	1.10 (36.1)	389.6 (13797)
Sand	0.20 (38.5)	0.16 (30.7)	0.16 (30.4)	0.06 (12.2)	1.98 (374.2)
Sandy Loam	0.79 (70.4)	0.65 (57.9)	0.51 (45.2)	0.36 (31.8)	6.52 (583.3)
Loam	0.73 (155.3)	0.36 (76.0)	0.27 (58.1)	0.21 (44.9)	12.11 (2572.9)

Number in parentheses refer to Koc values; Koc = Kads ÷ %O.C.; where %O.C. = % O.M.÷ 1.7

Desorption Coefficients of Atrazine and Its Main Degradates

Soil	Atrazine (G-30027)	Diaminochloro-s-triazine (G-28273)	Deisopropyl-atrazine (G-28279)	Deethyl-atrazine (G-30033)	Hydroxy-atrazine (G-34048)
Clay	9.12 (322.9)	7..80 (276.2)	12.36 (467.9)	8.14 (288.3)	515.89 (18271)
Sand	1.51 (285.5)	Value indeterminable due to limited adsorption			9.02 (1704.2)
Sandy Loam	7.27 (650.5)	8.06 (721.0)	15.28 (1366.9)	11.19 (1001.1)	14.87 (1330.4)
Loam	4.76 (1011.5)	6.87 (1459.9)	6.98 (1484.2)	3.92 (833.3)	11.28 (22397.6)

Number in parentheses refer to Koc values; Koc = Kdes ÷ %O.C.; where %O.C. = % O.M.÷ 1.7

Adsorption/Desorption Study: Soil Characteristics

Soil Type Texture	Bulk Density (g/cm^3)	Organic Matter (%)	pH	Sand %	Silt %	Clay %	CEC meq/100g
Clay	1.22	4.8	5.9	25	33	42	24.3
Sand	1.65	0.9	6.5	96	2	2	1.8
Sandy Loam	1.28	1.9	7.5	63	20	17	6.1
Loam	1.57	0.8	6.7	44	47	9	4.3

The dealkylated degradates (G-28273, G-28279, and G-30033) are more mobile than parent atrazine, but hydroxyatrazine (G-34048) is the least mobile of the degradates. Atrazine, its dealkylated degradates, and hydroxyatrazine are very mobile in the sand soil, as shown by their low (<2) adsorption coefficients (Kads) and the low adsorption Koc values (<500). In clay soil the adsorption coefficients and Koc values were higher for parent atrazine and the dealkylated degradates, but still fall below 5 and 500. However, adsorption of hydroxyatrazine was the strongest.

The results of the batch-equilibrium adsorption/desorption studies indicate that the dealkylated degradates are as likely (or even more likely) to leach to ground water as parent atrazine. However, soil characteristics must be taken into account when assessing the leaching potential in an specific region.

Terrestrial Field Dissipation (164-1)

The results of a field dissipation study with corn soil at Donaldsonville, Georgia (MRID: 42165504) predicted a half-life of 12.75 days with residues decreasing to less than 0.4 ppm on the 27-day sampling. AAtrex® Nine-O® was applied at a rate of 4.4 lb a.i./ac to a test corn plot of sandy loam soil on June 14, 1986. The residues of degradates G-34048. G-30033, and G-28279 found in the top 0-6" depth were significant lower (< 0.05 to 0.31 ppm) compared to the parent residues which ranged < 0.05 to 0.73 ppm. The leaching data for parent atrazine and metabolites at depths below 6-12" soil depth were generally below the screening level of 0.05 ppm.

The results of a field dissipation study with bare ground at Donaldsonville, Georgia (MRID 42165505) predicted a half-life of 38.52 days with residues decreasing to less than 0.5 ppm on the 451-day sampling. AAtrex® Nine-O® was applied at a rate of 18.0 lb a.i./ac to a field plot of unvegetated sandy loam soil on June 27, 1986. The residues of degradates G-34048. G-30033, and G-28279 found in the top 0-6" depth were significant lower (<0.05 to 2.16 ppm) compared to the parent residues which ranged <0.05 to 6.98 ppm. The leaching data for parent atrazine and metabolites at depths below 6-12" soil depth were generally below the screening level of 0.05 ppm.

The results of a field dissipation study with bare ground at Ripon, California (MRID 40431336, 42165506) predicted a half-life of 102.5 days. Atrazine (90% dry flowable) was applied at a nominal concentration of 18 lb ai/ac to a field plot of unvegetated sandy loam soil in July 1986. In the 0- to 6-inch depth, atrazine was 4.75 ppm (4.75 ppm total residues) immediately after treatment, decreased to 1.05 ppm (1.20 ppm total) at 90 days, and 0.67 ppm (0.94 ppm total) at 120 days, increased to 5.31 ppm (6.24 ppm total) at 180 days, then decreased to 0.50 ppm (0.63 ppm total) at 267 days and 0.20 ppm (0.26 ppm total) at 358 days post-treatment. The major degradates were G-34048. G-30033, and G-28279.

The results of a field dissipation study with bare ground at Hollandale, Minnesota (MRID 40431337, 42165507) indicated a half-life of 261 days. Atrazine (90% dry flowable) was applied at a nominal concentration of 20 lb ai/ac to a field plot of unvegetated loam soil in July 1986. In the 0- to 6-inch depth, atrazine was 4.23 ppm (5.06 ppm total residues) immediately after treatment, increased to 10.15 ppm (11.66 ppm total) at 14 days, decreased to 5.34 ppm (6.75 ppm total) at 28 days, and was 2.90 ppm (4.88 ppm total) at 360 days post-treatment. The major degradates were G-34048. G-30033, and G-28279.

The results of a field dissipation study with a corn soil at Hollandale, Minnesota (MRID 40431339, 42165508) yielded a half-life of 261 days. Atrazine (90% dry flowable) was applied at a nominal concentration of 4.4 lb ai/ac to a field plot of loam soil planted to corn in July 1986. In the 0- to 6-inch depth, atrazine was 1.20 ppm (1.37 ppm total residues) immediately after treatment, increased to 1.40 ppm (1.59 ppm total) at 2 days, ranged from 0.48 to 1.00 ppm (0.90 - 1.17 ppm total) with no discernable pattern between 7 and 290 days, and was 0.37 ppm (0.91 ppm total) at 360 days post-treatment. The major degradates were G-34048. G-30033, and G-28279.

The results of a field dissipation study with corn soil in Ripon, California (MRID 40431338, 42165509) indicated a half-life of 58 days. Atrazine (90% dry flowable), applied at a nominal concentration of 3.96 lb ai/ac to a field plot of sandy loam soil planted to corn in July 1986. In the 0- to 6-inch depth, atrazine was 1.15 ppm (1.15 ppm total residues) immediately after treatment, increased to 2.82 ppm (2.82 ppm total) at 7 days, decreased to 1.18 ppm (1.18 ppm total) at 14 days, decreased to 0.50 ppm (0.74 ppm total) at 60 days, and was 0.02 ppm (0.53 ppm total) at 358 days post-treatment. The major degradates were G-34048. G-30033, and G-28279.

Forestry Field Dissipation (164-3)

A field dissipation half-life of 87 days was estimated for exposed soil in a forestry study at Oregon City, Oregon (MRID Nos: 40431340, 42041405). Atrazine (90% G) was applied aerially at 4 lb ai/ac to 10 acres of an immature Douglas fir forest on April 4, 1985. In tree foliage samples, atrazine was 168.2 - 294.2 ppm immediately post-treatment, 76.7 - 88.0 ppm at 7 days, 6.6 - 10.5 ppm at 29 days, and 1.6 - 3.2 ppm at 88 days post-treatment. The registrant-calculated half-life for atrazine in foliage was 13 days.

In leaf litter samples, atrazine was 73.1 - 114.2 ppm immediately post-treatment, 21.8 - 27.9 ppm at 29 days, 7.2 - 8.1 ppm at 88 days, and 0.60 - 3.4 ppm at 364 days post-treatment; the registrant calculated half-life was 66 days. In soil (0- to 6-inch depth) that was not covered with leaf litter, atrazine concentration were variable with no discernible pattern, ranging from 0.075 to 4.3 ppm. G-30033 was isolated at up to 0.118 ppm. In the 6- to 12- and 12- to 18-inch soil depths, atrazine was < 0.05 to 0.432 ppm and < 0.05 to 0.110 ppm, respectively. In soil under leaf litter, atrazine concentration were variable in the 0- to 6-inch depth, ranging from 0.077 to 4.7 ppm, and were $\leq$0.088 ppm in the 6- to 12- and 12- to 18-inch depths.

Long-Term Terrestrial Field Dissipation (164-5)

The results of a long-term field dissipation study with corn soil at Hollandale, Minnesota, (MRID 40431339, 42089911) predicted a half-life of 402 days with an r^2 of 0.81. In the 0-6" soil samples, detectable residues of atrazine, G-30033, and G-34048 were found at 451, 510, 668, 847, 1032, 1211, and 1389 DAT (days after treatment), and detectable residues of G-28279 were found at 451, 510, 668, 847, and 1032 DAT. In the 6-12" soil samples, detectable residues of atrazine were found at 510, 668, 847, 1032, and 1211 DAT, detectable residues of G-30033 were found at 668, 847, and 1032 DAT, and detectable residues of G-34048 were found at 451, 510, 668, 847, 1032, 1211, and 1389 DAT. The 12-18" soil samples produced no detectable residues of atrazine, G-28279, G-30033, or G-34048. No detectable residues of atrazine, G-28279, or G-30033 were found in the 18-24" soil samples; however, detectable residues of G-34048 were found at 1211 and 1389 DAT. In the 24-36" soil samples, no detectable residues of atrazine, G-28279, G-30033, or G-34048 were found.

The results of a long-term field dissipation study with bare ground at Hollandale, Minnesota, (MRID 40431337, 42089912) predicted a half-life of 261 days with an r^2 of 0.94. In the 0-6" soil samples, detectable residues of atrazine, G-30033, and G-34048 were found at 449, 498, 659, 839, 1020, 1200, and 1378 DAT, and detectable residues of G-28279 were found at 449, 498, 659, 839, and 1020 DAT. Detectable residues of atrazine and G-34048 were found in the 6-

12" soil samples at 449, 498, 659, 839, 1020, and 1200 DAT, detectable residues of G-30033 were found at 449, 498, 659, 839, and 1200 DAT. In the 12-18" soil samples, detectable residues of atrazine were found at 449, 498, 659, 839, 1020, 1200, and 1378 DAT, no detectable residues of G-28279 or G-30033 were found, detectable residues of G-34048 were found at 449, 659, and 1200 DAT. In the18-24" soil samples, detectable residues of atrazine were found at 449, 498, 659, 839, and 1020 DAT, no detectable residues of G-28279 were found, detectable residues of atrazine were found only at 1020 DAT, detectable residues of G-28279 were found 449 and 498 DAT, detectable residues of G-30033 were only found at 498 DAT, and no detectable residues of G-34048 were found.

The results of a long-term field dissipation study with corn soil at Ripon, California, (MRID 40431338, 42089909) predicted a half-life of 102 days with an r^2 of 0.84. In the 0-6" soil samples, detectable residues of atrazine were found at 552 DAT, no detectable residues of G-30033 were found, and G-34048 were found at 460, 552, 726, 873, 1045 DAT samples. In the 6-12" soil samples, detectable residues of atrazine were found at 460 and 552 DAT, detectable residues of G-28279 and G-30033 were found only in the 460 DAT samples, and detectable residues of G-34048 were found at460, 552, 873, and 1045 DAT soils samples. At the 12-18" soil depth, detectable residues of atrazine were found at 460 DAT only, no detectable residues of G-28279 or G-30033 were found, and detectable residues of G-34048 were found in the 460, 552, and 873 DAT soil samples. In the 18-24" soil samples, detectable residues of atrazine and G-28279 were found in 460 and 552 DAT soil samples, no detectable residues of G-30033 were found, and detectable residues of G-34048 were found in the 460 and 873 DAT soil samples. No detectable residues of G-28279 were found in the 24-36" soil samples, while detectable residues of atrazine and G-30033 were found at 460 DAT, and residues of G-34048 were found at 460, 552, and 873 DAT.

The results of a long-term field dissipation study with bare ground at Ripen, California, (MRID 40431336, 42089910) predicted a half-life of 110 days with an r^2 of 0.92. In the 0-6" soil samples, detectable residues of atrazine and G-30033 were found only at 460 DAT, and detectable residues of G-34048 were found in 460, 552, and 837 DAT samples. No detectable residues of atrazine or G-28279 were found in the 6-12" soil samples, detectable residues of G-30033 were found only at 552 DAT, and detectable residues of G-34048 were found in the 460, 552, and 873 DAT soil samples. No detectable residues of atrazine, G-28279, or G-33033 were found in the 12-18" soil samples, while detectable residues of G-34048 were found in the 460, 552, and 873 DAT soil samples. In the18-24" soil samples, no detectable residues of atrazine, G-28279, or G-30033 were found, while detectable residues of G-34048 were found in the 460, 552, and 873 DAT soil samples. Detectable residues of atrazine, G-28279, G-30033, and G-34048 were found in the 24-36" soil samples for 460 DAT and residues of atrazine and G-34048 were also found at 873 DAT.

Bioaccumulation in Fish (165-4)

Based on an accepted study (MRID: 40431344), total [^{14}C]atrazine residues accumulated in bluegill sunfish with maximum bioconcentration factors of 7.7x, 12x, and 15x in edible tissues (body, muscle, skin, skeleton), nonedible tissues (fins, head, internal organs), and whole fish, respectively, during 28 days of exposure to uniformly ring-labeled [^{14}C]atrazineat 0.01 ppm in a flow-through system. After 21 days of depuration, [^{14}C]atrazine were 0.21 ppm in edible tissues,

0.38 ppm in nonedible tissues, and 0.28 ppm in whole fish; depuration rates were 74, 76, and 78%, respectively.

Spray Drift Data Requirements (201-1, 202-1)

The guidelines require data of droplet size spectrum and drift field evaluation. No atrazine-specific spray drift studies were reviewed. The registrant, Novartis, is a member of the Spray Drift Task Force (SDTF). The SDTF has completed and submitted to the Agency a series of studies intended to characterize spray droplet drift potential due to various factors, including application methods, application equipment, meteorological conditions, crop geometry and droplet characteristics. EFED is currently evaluating these studies. After its review, the Agency will determine whether a reassessment is warranted of the potential risks from the application of atrazine to nontarget organisms.

Degradates Detected in Laboratory Studies

There are two major types of degradates for atrazine. The first type of degradates are formed via dealkylation of the amino groups, for which mono- and fully dealkylated degradates are known. The second type of degradates are formed by substitution of a chloro group by a hydroxy group in either parent or dealkylated degradates.

The following table provides a summary of atrazine degradates detected in the laboratory studies discussed above.

Major Degradates	Photolysis in Water	Photolysis on Soil	Aerobic Soil	Anaerobic Soil	Anaerobic Aquatic
Deethylatrazine G-30033	X	X	X	X	X
Deisopropylatrazine G-28279	X	X	X	X	X
Diaminochlorotriazine G-28273	X	X	X	X	
Hydroxyatrazine G-34048		X	X	X	X
Deethylhydroxyatrazine GS-17794		X	X		
Deisopropylhydroxy-atrazine GS-17792		X	X		

Appendix III. Submitted Environmental Fate and Transport Studies

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Balu, K. 1991. Responses to the EPA review of the field dissipation study on Aatrex Nine-0 for terrestrial uses on bareground, Hollandale, Minnesota: Supplement to EPA MRID Number 40431337. Lab. Project Number: ABR-91064. 50 p. Unpublished study prepared and submitted by Ciba-Geigy Corp., Greensboro, NC. (MRID # 42165507).

Balu, K. 1991. Responses to the EPA review of the field dissipation study on Aatrex Nine-0 for terrestrial uses on bareground, Ripon, California: Supplement to EPA MRID Number 40431336. Lab. Project Number: ABR-91063. 110 p. Unpublished study prepared and submitted by Ciba-Geigy Corp., Greensboro, NC. (MRID # 42165506).

Balu, K. 1991. Responses to the EPA review of the field dissipation study on Aatrex Nine-0 for terrestrial uses on corn, Hollandale, Minnesota: Supplement to EPA MRID Number 40431339. Lab. Project Number: ABR-91066. 49 p. Unpublished study prepared and submitted by Ciba-Geigy Corp., Greensboro, NC. (MRID # 42165308).

Balu, K. 1991. Responses to the EPA review of the field dissipation study on Aatrex Nine-0 for terrestrial uses on corn, Ripon, California: Lab. Project Number: ABR-91065. 111 p. Unpublished study prepared and submitted by Ciba-Geigy Corp., Greensboro, NC. (MRID # 42165509).

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Froelich, L., T. Bixler, C. Peake et al. 1982. Soil adsorption/desorption characteristics of FMC 57020: M-4861. Unpublished study received Oct 1, 1982 under 279-EX-93; submitted by FMC Corp., Philadelphia, PA; CDL:248476-D. (MRID # 00116620).

Guy, S. 1987. Field dissipation on Aatrex Nine-0 for terrestrial uses on bareground in Donalsonville, GA: Lab. Project Number: 1641-86-71-01-21E-27. 317 p. Unpublished study prepared by Landis International and Others; submitted by Ciba-Geigy Corp., Greensboro, NC. (MRID # 42165505).

Guy, S. 1987. Field dissipation on Aatrex Nine-0 for terrestrial uses on corn in Donalsonville, GA: Lab. Project Number: 1641-86-71-01-06B-26. 325 p. Unpublished study prepared by Landis International and Others; submitted by Ciba-Geigy Corp., Greensboro, NC. (MRID # 42165504).

Hardies, D. E. and D. Y. Studer. 1982. Soil thin-layer chromatography of PPG-1292: BRC 22593. Unpublished study received April 5, 1982 under 2F2666; submitted by PPG Industries, Inc., Barberton, Ohio; CDL:070755-J. (MRID # 00098254).

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Schabacker, D. 1991. Summary report: Aqueous photolysis of carbon 14-atrazine under natural and artificial light. Lab. Project Number: 12112 A: 12112 B. 185 p. Unpublished study prepared by Agrisearch Inc., Frederick, MD; submitted by Ciba-Geigy Corp., Greensboro, NC. (MRID # 42089904).

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Spare, W. 1989. Adsorption/desorption of ^{14}C-G-28279: Agrisearch Project No. 12170. 57 p. Unpublished study prepared by Agrisearch, Inc., Frederick, MD; submitted by Ciba-Geigy Corp., Greensboro, NC. (MRID # 41257905).

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Appendix IV. Drinking Water Characterization

The drinking water characterization is being reported in a separate report, entitled "Drinking Water Exposure Assessment for Atrazine and Various Chloro-triazine and Hydroxy-triazine Degradates." The conclusions and summary of results (Chapter 10) are excerpted below.

10. Conclusions and Summary of Results

10.1) Atrazine concentrations in the PLEX and comparison to Office of Drinking Water MCL and short term HALs for atrazine

Of the 21,241 ground, surface, and blend water source CWSs in 21 states with atrazine data in the PLEX database through 1998, 2,386 CWSs (11.2%) had one or more atrazine detections above limits of quantification (LOQs) (Table 4-2 which is Table 4.2-3 of MRID 450587-04). Of a total of 88,766 samples in the database, 8,685 (9.8%) had detections above the LOQs (Table 4-2). The LOQs varied from 0.01 to 0.5 ug/L, but were typically at 0.1 ug/L (Table 4-3 which is Table 3.2-6 of MRID 450587-04).

The population and % of the assessed population exposed to 1998, 1997, 1996, 1995, 1994, and 1993 annual mean atrazine concentrations $\geq$ 3 ug/L were 16,000 people (0.02%), 129,000 people (0.18%), 156,000 people (0.19%), 506,000 people (0.79%), 331,000 people (0.58%), and (76,500 people (0.17%), respectively. The assessed populations for 1998, 1997, 1996, 1995, 1994, and 1993 were approximately 79.9, 71.6, 82.3, 64.0, 57.1, and 45.0 million, respectively.

The # of CWSs and % of the assessed CWSs with 1998, 1997, 1996, 1995, 1994, and 1993 annual mean atrazine concentrations $\geq$ 3 ug/L were 4 CWSs (0.05%), 26 CWSs (0.31%), 73 CWSs (0.92%), 11 CWSs (0.14%), 95 CWSs 1.49%), and 19 CWSs (0.49%), respectively. The # of assessed CWSs in those years were 8548, 8300, 7944, 7909, 6395, and 3913 CWSs, respectively.

Of the 21,241 CWSs with atrazine data in the PLEX database, 182 CWSs had one or more annual mean atrazine concentrations $\geq$ the MCL of 3 ug/L during the 1993-1998 period (Tables 4-1 and 4-2). Of those 182 CWSs, 81 are suppliers and 101 are purchasers. Of the 81 suppliers, 74, 5, and 2 have surface water, blend, and ground water sources, respectively. Of the 81 suppliers, 33 are in Illinois, 16 are in Missouri, 12 are in Kansas, 12 are in Ohio, 4 are in Kentucky, 2 are in Indiana, and one each are in North Carolina and Texas (Table 4-2).

The highest atrazine concentration (42 ug/L) reported in the PLEX database from 1993 through 1998 is well below the Office of Drinking Water short term HALs for atrazine of 100 ug/L. However, because only one sample was collected per quarter/CWS in the PLEX database, reported maximum atrazine concentrations in the PLEX database may often be substantially less than actual peak concentrations. Because the VMS (on 100 surface water source CWSs) and the ARP surface water monitoring study (on 175 surface water source CWSs) have substantially more time series data than the PLEX database, observed maximum atrazine concentrations in those studies for a given CWS should generally be closer to actual peak atrazine concentrations in the CWS than observed maximum atrazine concentrations for the

same CWS in the PLEX database. However, the maximum reported atrazine concentrations in those studies (63.5 and 49.5 ug/L) were still well below the Office of Drinking Water short term HALs for atrazine of 100 ug/L.

10.2) Atrazine concentrations in the Rural Well Survey and comparison to Office of Drinking Water MCL and short term HALs for atrazine

In the Rural Well Survey from September 1992 to March 1995, one sample was collected from each of 1505 wells and analyzed for atrazine, and various chloro-triazine and hydroxytriazine degradates. The maximum, 99th percentile, and 95th percentile atrazine concentrations were 12.0, 2.4, and 0.87 ug/L.

Eight wells (out of the 1,505 wells sampled in the Rural Well Survey) had atrazine concentrations exceeding the MCL of 3 ug/L. Because only one sample was collected from each well, it is not known how many if any of those 8 wells had annual mean atrazine concentrations exceeding 3 ug/L. In the ARP ground water monitoring of 177 wells from May 1995 to March 1998, 2 of the 177 wells had a maximum annual mean atrazine concentration (14.3 and 4.97 ug/L based on running annual means) > 3 ug/L.

The highest atrazine concentration detected in the Rural Well Survey (12 ug/L) was much less than the short term HAL of 100 ug/L. However, because only one sample was collected per well in the Rural well Survey, the reported maximum atrazine concentration in the Rural Well Survey may be substantially less than the actual peak concentration. In the ARP ground water monitoring study of only 177 wells, but which included 12 samples/well/year over a 3 year period, one well had a maximum atrazine concentration (132 ug/L) greater than the short term HAL of 100 ug/L. However, the next highest atrazine concentration (11.0 ug/L) was well below the HAL.

10.3) Regression estimated, annual mean and annual maximum total chloro-triazine concentrations in the surface water portion of the PLEX database and comparison to HED sub-chronic/chronic and acute DWLOCs.

The regression estimated, highest annual mean total chloro-triazine concentration (17 ug/L) for surface water source CWSs in the PLEX database from 1993 through 1998 is slightly below the sub-chronic/chronic HED DWLOC of 18 ug/L for children and infants and well below the sub-chronic/chronic HED DWLOC of 63 ug/L for adults.

The assessed populations in the surface water portion of the Novartis PLEX database for 1998, 1997, 1996, 1995, 1994, and 1993 were approximately 44.0, 38.2, 41.5, 31.4, 24.0, and 23.9 million, respectively. The # of assessed surface water source CWSs in those years were 2494, 2132, 2547, 1699, 1700, and 1212, respectively.

The regression estimated, highest total chloro-triazine concentration (59.8 ug/L) for surface water source CWSsin the PLEX database from 1993 through 1998 is well below the single HED acute DWLOC of 298 ug/L (for pregnant women).

In the PLEX database of atrazine data (collected to comply with the monitoring requirements of the SDWA), the annual maximum reported atrazine concentration for a CWS also represents its annual maximum reported 3-month quarterly mean because only one sample is generally collected per quarter (3 months). Therefore, the EFED compared regression estimated annual maximum total chloro-triazine concentrations to HED chronic as well as acute DWLOCs. The actual annual maximum quarterly mean for a CWS may be lower or higher than the annual maximum reported atrazine concentration for the CWS.

The population and the % of the assessed population exposed to estimated 1998, 1997, 1996, 1995, 1994, and 1993 annual maximum total chloro-triazine concentrations $\geq$ the lowest HED sub-chronic/chronic DWLOC of 18 ug/L for children and infants were 1450 people (0.003%), 105,721 people (0.28%), 40,586 people (0.10%), 0 people (0.0%), 210,544 people (0.84%), and 184,092 people (0.77%), respectively. The assessed populations in the surface water portion of the Novartis PLEX database for 1998, 1997, 1996, 1995, 1994, and 1993 were approximately 44.0, 38.2, 41.5, 31.4, 24.0, and 23.9 million, respectively.

The # of CWSs and % of the assessed CWSs with 1998, 1997, 1996, 1995, 1994, and 1993 annual maximum total chloro-triazine concentrations $\geq$ the lowest HED sub-chronic/chronic DWLOC of 18 ug/L for children and infants were 2 CWSs (0.08%), 9 CWSs (0.42%), 19 CWSs (0.75%), 0 CWSs (0.0%), 30 CWSs (1.77%), and 3 CWSs (0.25%), respectively. The # of assessed surface water source CWSs in those years were 2494, 2132, 2547, 1699, 1700, and 1212 CWSs, respectively.

The identities of, and populations served by CWSs with annual maximum total chloro-triazine concentrations $\geq$ the HED sub-chronic/chronic DWLOC of 18 ug/L for children and infants can be obtained from the cumulative exceedence tables in Sub-Appendix A-5.

The regression estimated, highest annual maximum total chloro-triazine concentration (59.8 ug/L) for surface water source CWSs in the PLEX database from 1993 through 1998 was slightly below the HED sub-chronic/chronic DWLOC of 63 ug/L for adults.

10.4) Comparison of total chloro-triazine and total hydroxy-triazine concentrations in the Rural Well Survey to HED DWLOCs

One well (out of 1505 sampled in the Rural Well Survey) had a total chloro-triazine concentration equaling the HED sub-chronic/chronic DWLOC of 18 ug/L for the chronic exposure of children and infants, respectively. No wells had total chloro-triazine concentrations exceeding the HED sub-chronic/chronic DWLOC of 18 ug/L for children and infants, the HED sub-chronic/chronic DWLOC of 63 ug/L for adults or the single HED acute DWLOC of 298 ug/L for adult women.

The highest total hydroxy-triazine concentration detected (7.66 ug/L) was much less than the lowest HED chronic DWLOC of 99 ug/L for children and infants.

Appendix V. Documentation of Water Resource Modeling (PRZM3-EXAMS & GENEEC)

Aquatic Exposure Assessment

Modeling Approach

For aquatic exposure assessment, the tier II refinement approach with PRZM (Pesticide Root Zone Model) and EXAMS (EXposure Analysis Modeling System) was simulated to generate the Estimated Environmental Concentrations (EEC's).

The environmental fate data for atrazine used in the tier 2 refined modeling are summarized in the following Table

.

Input Parameters for PRZM (version 3.12)

Variable (units)	Variable Description	Input Value	Source of Info/Reference
DWRATE(1)[1] (day^{-1})	Dissolved phase pesticide decay rate in surface horizon	DWRATE(1) = DSRATE(1) 4.748×10^{-3}	Aerobic soil metabolism study (GLN 162-1) 140 and 146 days
DSRATE(1)[1] (day^{-1})	Adsorbed phase pesticide decay rate in surface horizon		
DWRATE(2) (day^{-1}) DWRATE(3) (day^{-1})	Dissolved phase pesticide decay rate in 1st, and 2nd subsurface horizon	DWRATE(2) = DSRATE(2) 4.359×10^{-3} DWRATE(3) = DSRATE(3) 4.359×10^{-3}	Anaerobic soil/ anaerobic aquatic metabolism study (GLN 162-2/3) 159 days
DSRATE(2) (day^{-1}) DSRATE(3) (day^{-1})	Adsorbed phase pesticide decay rate in 1st and 2nd subsurface horizon		
KD(1) KD(2) KD(3) ($cm^3\ gm^{-1}$ or mL g^{-1} or L kg^{-1})	Pesticide partition or distribution coefficients for each horizon	use KOC value of 87.78 to estimate KD at each horizon	Mobility - Adsorption/Desorption study (GLN 163-1) average of 86.9, 38.5, 70.4, and 155.3
DEPI (cm)	Incorporation depth	Actual or pesticide label	Product label

TAPP ($kg\ ha^{-1}$)	Application rate	Maximum label rate	Product label
APPEFF (decimal)	Application efficiency	0.75 for aerial spray; 0.90 for ground spray.	Product label; AGDRIFT[2]
DRFT	Spray drift fraction	0.05 for aerial spray; 0.01 for ground spray.	AGDRIFT[2]

Input Parameters for EXAMS (Version 2.97.5)

Variable (units)	**Variable Description**	**Input Value**	**Source of Info/Reference**
HENRY ($atm\text{-}m^3mole^{-1}$)	Henry's law constant	2.58×10^{-9}	
KBACW[1] $(cfu/mL)^{-1}\ hour^{-1}$	Bacterial biolysis in water column	9.89×10^{-5}	twice of aerobic soil metabolism half-life (146 x2)
KBACS[1] $(cfu/mL)^{-1}\ hour^{-1}$	Bacterial biolysis in benthic sediment	4.75×10^{-5}	608 days
KDP ($hour^{-1}$)	Direct photolysis	1.72×10^{-4}	335 days
KBH ($mole^{-1}\ hour^{-1}$) KNH ($hour^{-1}$) KAH ($mole^{-1}\ hour^{-1}$)	Base hydrolysis Neutral hydrolysis Acid hydrolysis	0.0 0.0 0.0	Stable
KOC ($mL\ g^{-1}$ O.C.)	Partition coefficient for organic carbon	87.78	average of 86.9, 38.5, 70.4, and 155.3
MWT ($g\ mole^{-1}$)	Molecular weight	215.69	
SOL ($mg\ L^{-1}$)	Aqueous solubility	33	
QUANT	Reaction quantum yield for direct hydrolysis	0	
VAPR (torr)	Vapor pressure	3×10^{-7}	

PRZM

PRZM (Version 3.12) relates pesticide movement to temporal variations of hydrology, agronomy, pesticide chemistry and meteorology. In order to run PRZM, four types of input data are needed: meteorology, soil, hydrology and pesticide chemistry. Except for the pesticide chemistry, the other three types of input data were adopted based on the standard scenarios established by the Water Quality Tech Team (WQTT) of EFED.

Based on the rainfall records and crop productions, the modeling scenarios chosen to represent the high runoff potential are listed below:

Use	Site/Year	MLRA*	Soil	Hydrologic Soil Group
Corn	Ohio (48' ~83')	111	Cardington Silt Loam	C
Sugarcane	Louisiana (64'~83')	131	Sharkey Clay	D
Sorghum	Kansas (48' ~ 83')	112	Dennis Silt Loam	C

*MLRA represents Major Land Resource Area, which are geographically associated land resource units (USDA, 1981).

The meteorology parameters including precipitation, evaporation and air temperature were obtained from ORD, Athens Laboraotry. The soil properties including layer depth, soil texture class, soil composition (i.e., percentage sand, silt, clay, and organic matter), bulk density, field capacity, wilting point, and available water for each selected soil were extracted from PIRANHA databases.

EXAMS

The operation of EXAMS involved three types of data inputs: Environment, Load and Chemical. The standard Georgia farm pond data file was used to describe the Environment data input. The P2E-C1.D(X) [where "X" representing a two-digit number from 48 to 83, or 64 to 83], files generated by PRZM were used as the Load data input. The Chemical data input was created based on the E. Fate profile of atrazine.

EXAMS was run using data from 36 years using Mode 3 which used monthly environmental data and the daily pulse loads of runoff and spray drift. For each year simulated, the maximum annual peak, 96-hour average, 21-day average, 60-day average, 90-day average values, and the annual mean were extracted from the EXAMS output file REPORT.XMS with the TABLE20.EXE post-processor. The 10 year return EECs (or 10% yearly exceedance EECs) of corn, sugarcane, and sorghum listed in the Table below were calculated by linear interpolation between the third and fourth largest values by the program TABLE20.EXE.

Results - Aquatic EECs

The refined tier II approach with PRZM/EXAMS was implemented. The upper tenth percentile concentration values, expressed in ppb (ug/L), are summarized below. The results of three uses, corn, sugarcane, and sorghum, were based on the standard scenarios provided by the Water Quality Tech Team (WQTT) to predict reasonable high exposure values, i.e., soils with high runoff potential and heavy rainfall amounts.

Use	Peak	96-hr average	21-d average	60-d average	90-d average
Corn	38.24	38.02	37.18	35.50	34.16
Sugarcane	205.10	204.10	202.20	198.10	194.20
Sorghum	72.70	72.31	70.64	67.74	65.86

The modeling results indicate that atrazine does have the potential to move into surface waters, especially for sugarcane use.

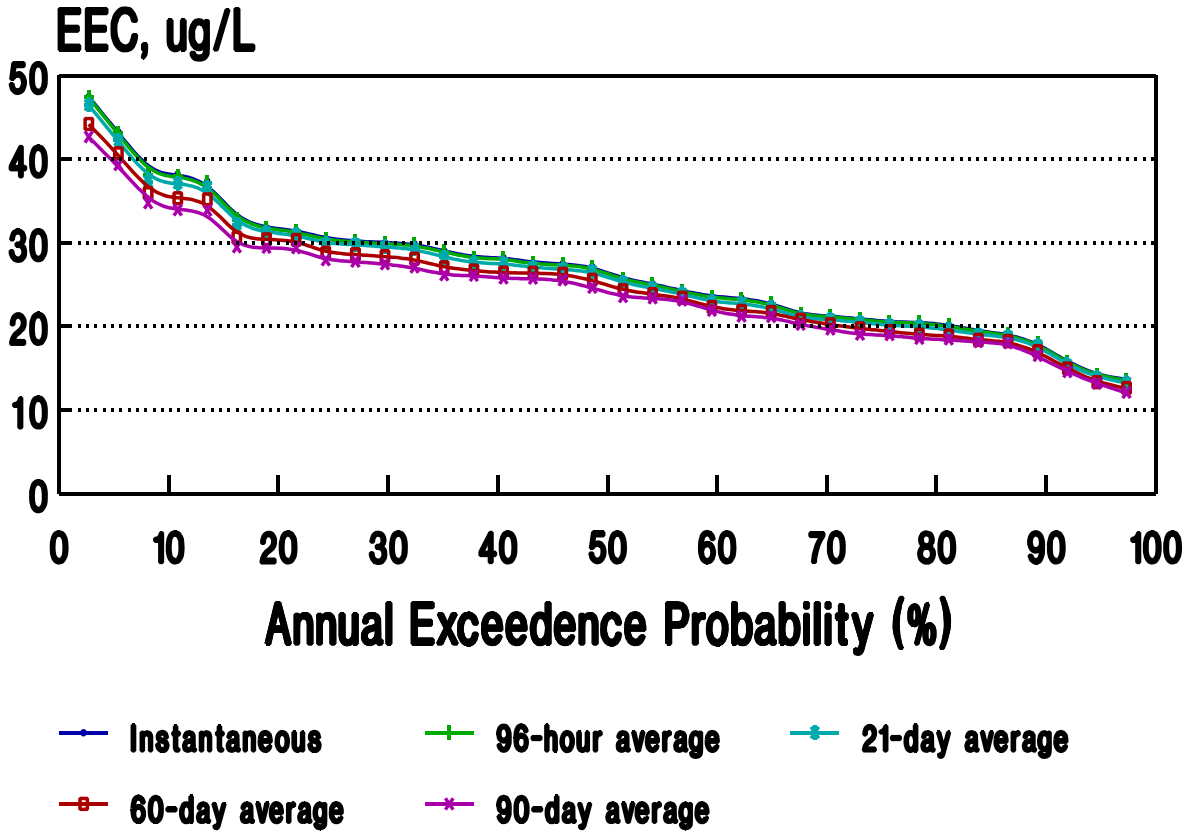
The post-processor, LOAD.EXE, was used to estimate the chemical contributions of runoff, erosion and spray drift to the standard farm pond. The results expressed as percentages are tabulated below:

Percent of Pesticide Loadings from Different Sources to the Standard Pond

Use	**Runoff**	**Erosion**	**Spray Drift**
Corn	55.03%	3.47%	41.50%
Sugarcane	99.15%	0.85%	0.01%
Sorghum	71.80%	5.29%	22.91%

The erosion losses were the smallest among the three components, except for sugarcane use scanario. Most of the atrazine losses to aquatic environments are from runoff. Therefore, any mitigation approaches should focus on reducing chemical runoff.

EEC Plot - Atrazine Use on Corn
Major Land Resource Area (MLRA): 111
Indiana and Ohio Till Plain



Cardington Silt Loam (HSG: C)
Aerial Application
Preplant @ 2.0 lb a.i./ac

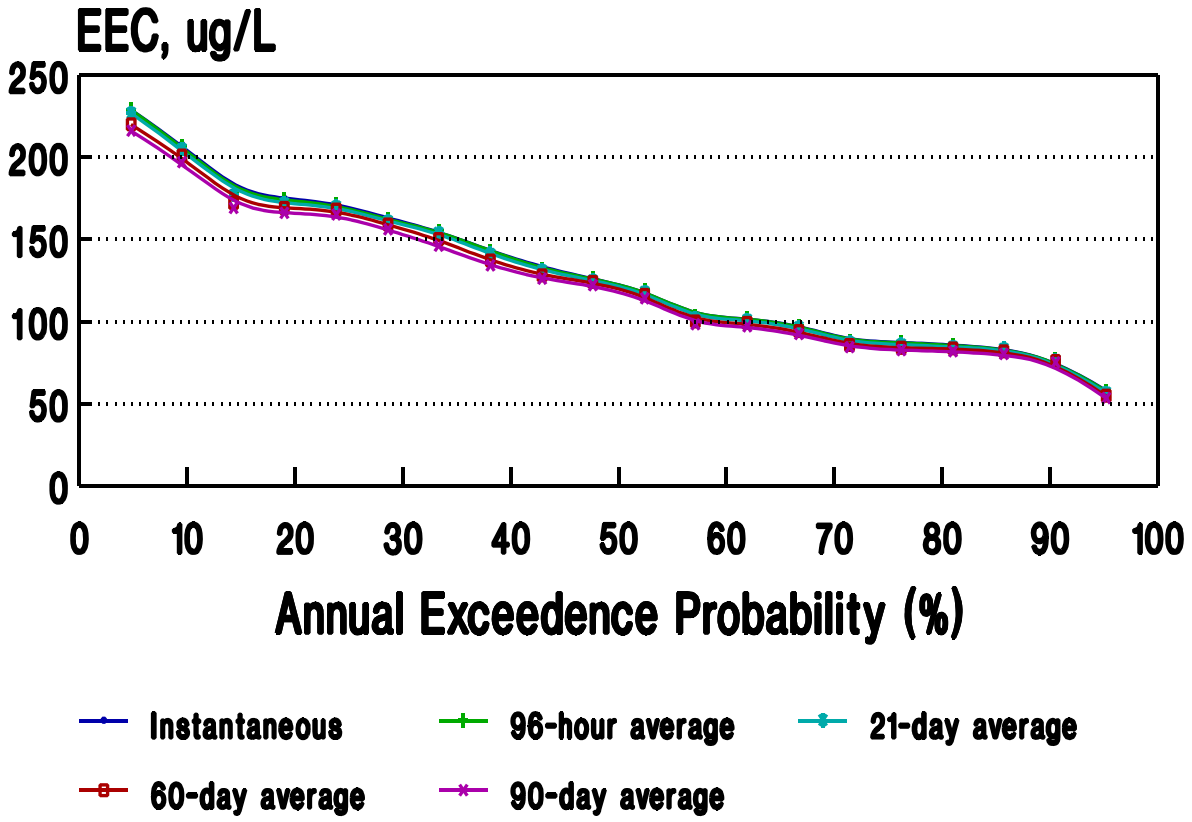
ATRAZINE USE ON CORN

WATER COLUMN DISSOLVED CONCENTRATION (PPB)

YEAR	PEAK	96 HOUR	21 DAY	60 DAY	90 DAY	YEARLY
1948	13.680	13.580	13.260	12.610	12.080	6.926
1949	14.140	14.060	13.880	13.320	13.190	10.440
1950	15.760	15.680	15.400	14.960	14.560	11.290
1951	23.380	23.250	22.760	21.830	21.200	15.030
1952	20.560	20.490	20.140	19.440	18.970	15.590
1953	29.880	29.730	29.300	28.060	27.050	19.430
1954	22.840	22.720	22.230	21.710	21.140	18.160
1955	19.090	19.010	18.790	18.220	18.000	15.290
1956	20.920	20.820	20.500	19.740	19.020	15.070
1957	32.860	32.720	32.200	30.610	29.410	20.940
1958	38.210	37.980	37.120	35.310	33.860	25.720
1959	37.370	37.200	36.610	35.180	33.910	27.120
1960	27.500	27.360	27.060	26.420	25.730	22.390
1961	27.630	27.470	26.840	25.580	24.640	20.060
1962	28.280	28.150	27.530	26.390	25.530	20.650
1963	25.710	25.580	25.240	24.330	23.520	19.600
1964	21.240	21.170	20.820	20.250	19.650	16.620
1965	20.510	20.420	19.980	19.010	18.450	14.920
1966	18.040	17.960	17.740	17.040	16.480	13.550
1967	30.050	29.900	29.490	28.380	27.460	18.950
1968	47.490	47.380	46.480	44.190	42.650	30.330
1969	43.270	43.080	42.260	40.680	39.310	32.090
1970	31.790	31.660	31.230	30.330	29.360	25.740
1971	28.230	28.100	27.580	26.680	26.080	21.600
1972	31.520	31.370	30.980	30.390	29.460	22.600
1973	25.110	25.010	24.570	23.860	23.370	20.090
1974	38.300	38.100	37.330	35.930	34.730	24.720
1975	27.160	27.040	26.580	26.280	25.750	22.750
1976	23.580	23.450	22.950	22.300	21.890	18.560
1977	19.460	19.380	19.020	18.390	18.120	15.750
1978	21.450	21.350	21.020	20.770	20.220	15.880
1979	20.200	20.090	19.640	18.900	18.530	15.320
1980	30.210	30.110	29.910	28.800	27.760	19.970
1981	30.530	30.360	29.820	28.610	27.920	22.190
1982	29.040	28.910	28.290	27.060	26.140	21.380
1983	24.270	24.140	23.910	23.410	23.120	19.420
Upper 10th Percentile	38.237	38.016	37.183	35.496	34.156	26.154

MEAN OF ANNUAL VALUES = 19.337
STANDARD DEVIATION OF ANNUAL VALUES = 5.287
UPPER 90% CONFIDENCE LIMIT ON MEAN = 20.642

EEC Plot - Atrazine Use on Sugarcane
Major Land Resource Area (MLRA): 131
Southern Mississippi Valley Alluvium



Sharkey Clay (HSG: D)
Aerial Application
preemergence @ 4.0 lb a.i./ac

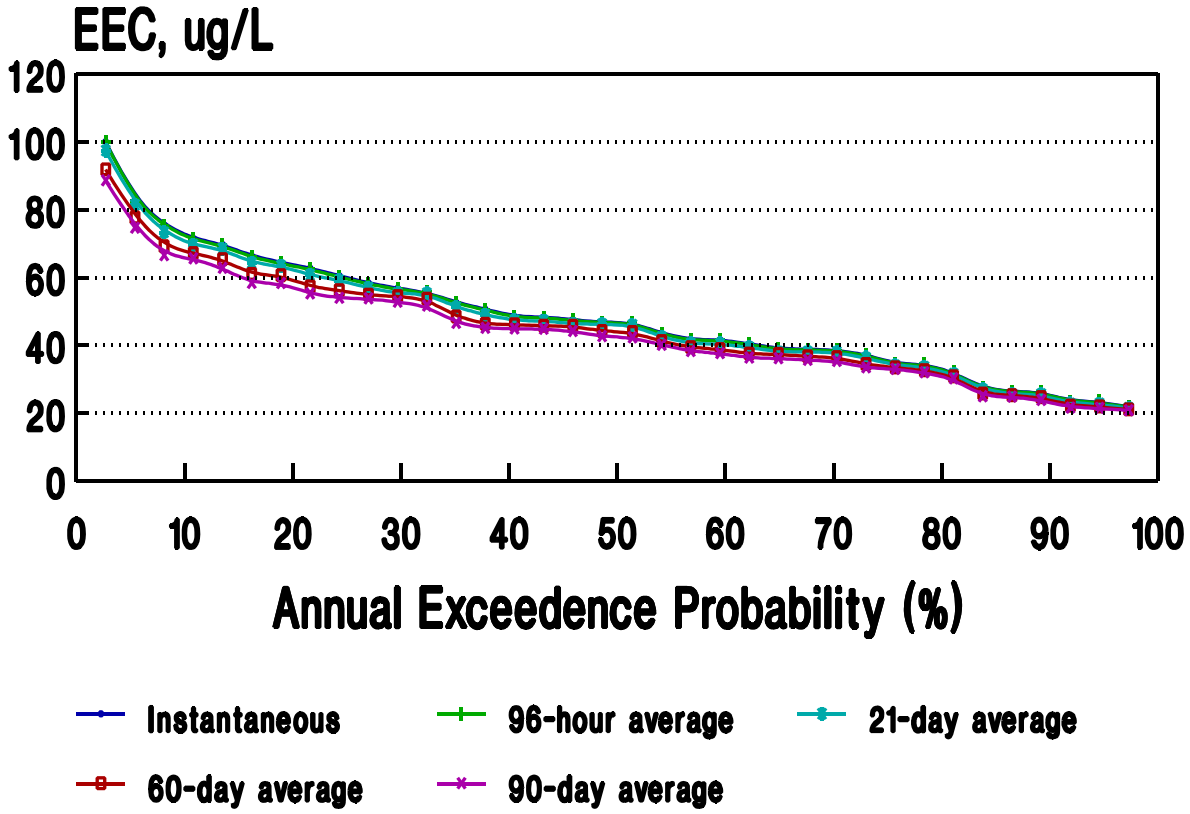
ATRAZINE USE ON SUGARCANE

WATER COLUMN DISSOLVED CONCENTRATION (PPB)

YEAR	PEAK	96 HOUR	21 DAY	60 DAY	90 DAY	YEARLY
1964	57.960	57.690	56.610	54.640	53.220	40.190
1965	87.580	87.270	86.000	83.530	81.670	63.870
1966	133.000	132.000	131.000	128.000	126.000	98.030
1967	103.000	103.000	102.000	99.860	98.170	79.370
1968	83.860	83.640	83.320	81.640	80.150	64.630
1969	119.000	119.000	118.000	116.000	114.000	88.150
1970	76.900	76.760	76.190	75.860	75.000	61.140
1971	85.600	85.320	84.500	83.870	82.530	64.820
1972	88.110	87.850	87.220	85.570	84.230	67.330
1973	97.760	97.450	96.430	94.080	92.280	72.340
1974	102.000	102.000	101.000	98.940	96.890	76.860
1975	143.000	143.000	141.000	137.000	134.000	105.000
1976	163.000	162.000	161.000	159.000	156.000	123.000
1977	175.000	174.000	172.000	169.000	166.000	131.000
1978	126.000	126.000	125.000	124.000	122.000	98.470
1979	155.000	155.000	154.000	150.000	146.000	115.000
1980	229.000	229.000	227.000	220.000	216.000	168.000
1981	208.000	207.000	205.000	201.000	197.000	157.000
1982	172.000	171.000	170.000	168.000	165.000	132.000
1983	179.000	178.000	177.000	172.000	169.000	134.000
Upper 10th Percentile	205.100	204.100	202.200	198.100	194.200	154.700

MEAN OF ANNUAL VALUES = 97.010
STANDARD DEVIATION OF ANNUAL VALUES = 35.121
UPPER 90% CONFIDENCE LIMIT ON MEAN = 108.774

EEC Plot - Atrazine Use on Sorguhm
Major Land Resource Area (MLRA): 112
Cherokee Prairies



Dennis Silt Loam (HSG: C)
Aerial Application
Preplant @ 2.0 lb a.i./ac

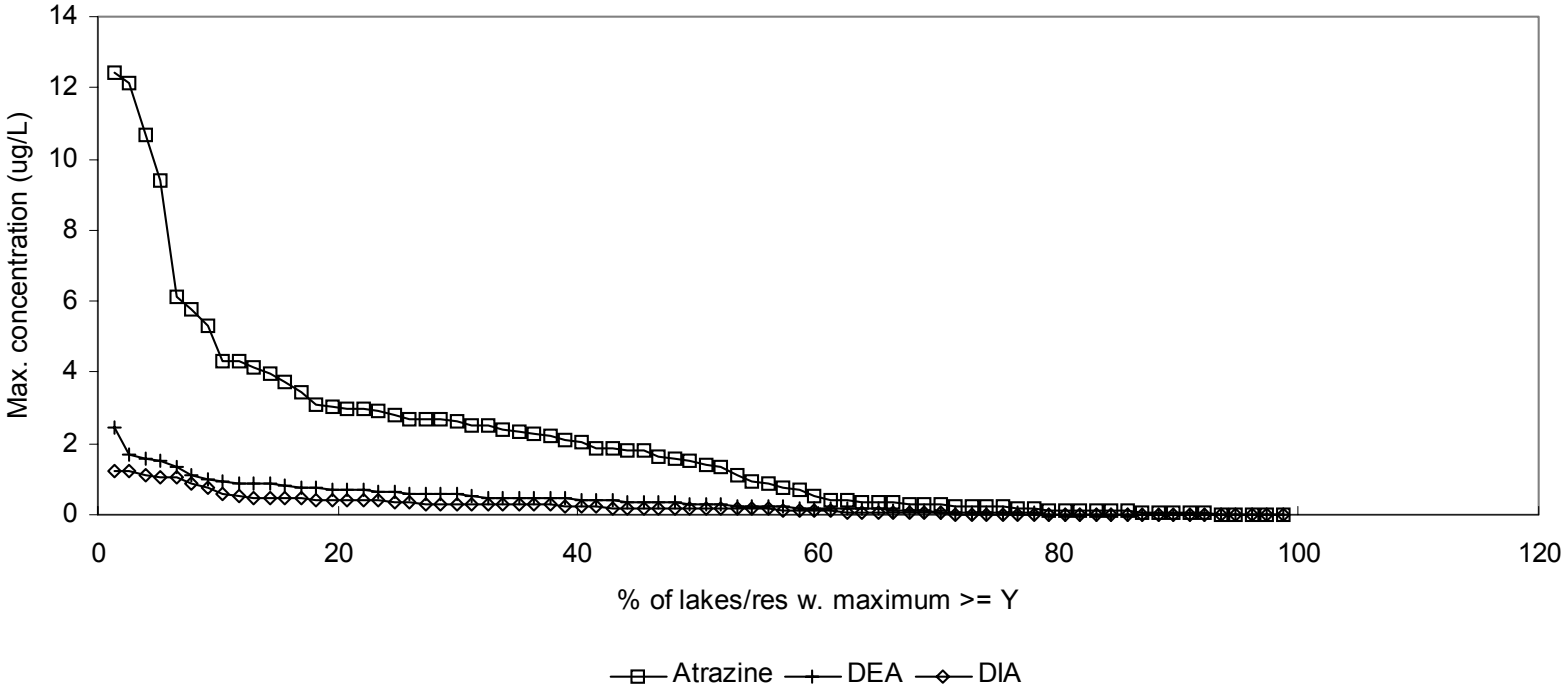
ATRAZINE USE ON SORGHUM

WATER COLUMN DISSOLVED CONCENTRATION (PPB)

YEAR	PEAK	96 HOUR	21 DAY	60 DAY	90 DAY	YEARLY
1948	50.720	50.410	49.010	46.270	44.190	21.970
1949	38.890	38.690	38.080	36.510	35.360	31.360
1950	32.120	31.940	31.560	30.860	30.210	26.320
1951	39.050	38.820	38.120	37.420	36.160	27.780
1952	66.370	65.950	64.290	60.950	58.370	39.860
1953	48.530	48.280	47.310	46.190	44.890	40.210
1954	34.520	34.350	34.090	33.460	33.020	29.870
1955	26.390	26.240	25.620	25.270	24.940	22.820
1956	23.430	23.310	22.760	22.200	21.590	19.080
1957	27.430	27.270	27.000	25.740	24.820	19.470
1958	23.490	23.370	22.830	21.960	21.510	18.600
1959	21.910	21.780	21.530	21.120	20.830	17.390
1960	26.250	26.140	25.560	24.690	23.900	18.820
1961	41.740	41.490	40.480	39.400	38.310	27.360
1962	64.500	64.110	63.410	60.600	58.330	41.460
1963	62.780	62.390	60.740	57.330	55.260	45.510
1964	48.410	48.170	47.260	45.690	44.840	41.030
1965	38.640	38.440	37.980	36.700	35.710	31.830
1966	40.540	40.310	39.390	37.540	36.360	29.680
1967	43.540	43.290	42.440	41.200	40.160	31.790
1968	37.350	37.160	36.290	34.420	33.420	29.770
1969	41.670	41.430	40.520	38.860	37.650	29.820
1970	60.560	60.200	59.150	56.200	53.950	38.740
1971	46.830	46.590	45.990	44.210	42.660	37.700
1972	34.560	34.360	33.620	32.650	32.020	29.550
1973	58.390	58.050	56.980	54.830	52.810	37.050
1974	100.000	99.840	97.310	91.840	88.580	60.470
1975	82.780	82.440	81.330	77.590	74.640	64.500
1976	55.640	55.560	55.250	54.460	53.760	47.640
1977	52.650	52.410	51.200	48.460	46.600	39.210
1978	47.580	47.330	46.240	43.870	42.320	36.220
1979	56.810	56.490	55.300	53.680	51.700	39.190
1980	75.400	75.050	73.280	69.150	66.500	48.800
1981	71.540	71.140	69.510	67.140	65.590	54.300
1982	69.750	69.380	68.410	65.320	62.780	52.210
1983	46.710	46.650	46.380	45.720	45.120	39.610
Upper 10th Percentile	72.698	72.313	70.641	67.743	65.863	52.837

MEAN OF ANNUAL VALUES = 35.194
STANDARD DEVIATION OF ANNUAL VALUES = 11.797
UPPER 90% CONFIDENCE LIMIT ON MEAN = 38.105

Fig. USGS 1992 Lake/Reservoir
Misc. maxima cumul. exceed. curves



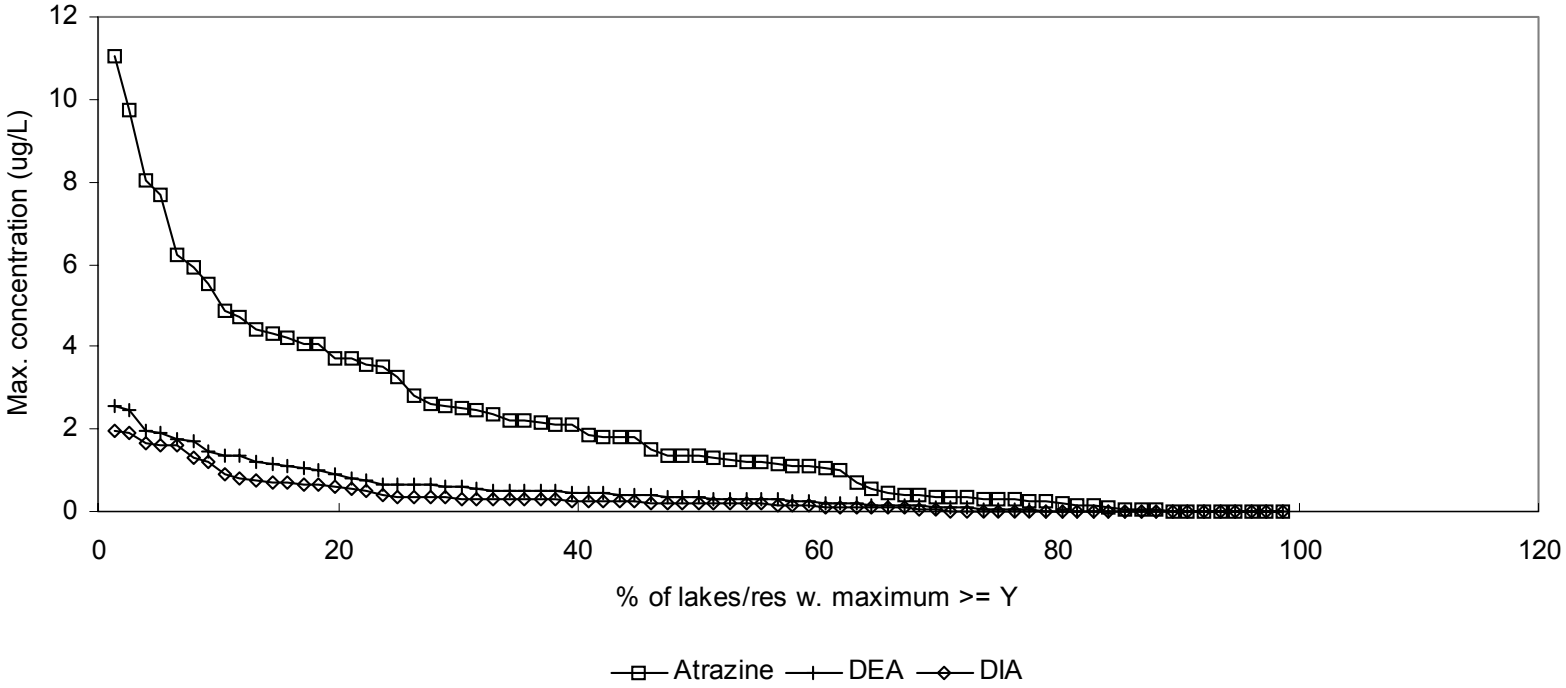
APPENDIX VI. Lake and Reservoir Monitoring Studies and Data Plots

USGS 1992-1993 Study of 76 Mid-Western Reservoirs (USGS Open-File Report 96-393):

The USGS sampled the outflows from 76 mid-western reservoirs 8 times (approximately once every two months) from April 1992 through September 1993 (USGS Open-File Report 96-393). The samples were analyzed for a number of pesticides and pesticide degradates including atrazine, de-ethyl atrazine (DEA), and de-isopropyl atrazine (DIA). The reservoirs were selected from a list of approximately 440 reservoirs in 11 mid-western states. The locations of the reservoirs are shown below. Information about the sampled reservoirs is supplied in table.

The sampling frequency was inadequate for EFED to provide an atrazine, time series for the reservoirs. However, EFED generated 1992 and 1993 cumulative exceedence curves of maximum annual atrazine, DEA, and DIA concentrations versus the % of reservoirs with equal or greater annual maximum concentrations.

Fig. USGS 1993 Lake/Reservoir
Misc. maxima cumul. exceed. curves



APPENDIX VII. Stream and River Monitoring Studies and Data Plots

USGS 1989-1990 Reconnaissance Study of Mid-Western Streams (USGS Open-File Report 93-457):

In 1989, the USGS collected one "pre-application" sample, one "post-application" sample and one "Fall" sample from 52, 129, and 143 mid-western streams, respectively, across 10 states. In 1990, the USGS collected one "pre-application" sample, and one "post-application" sample from 52 and 50 mid-western streams, respectively, across 10 states. "Pre-application" samples were generally collected in March or April before the applications of various herbicides. "Post-application" samples were collected during May or June during the first runoff event following the bulk of herbicide applications. "Fall" samples were generally collected in October or November.

The samples were analyzed for a number of pesticides including atrazine, DEA, and DIA. The number of samples collected at each site (1-3 depending upon the site) was not adequate for EFED to generate atrazine, DEA, and DIA time series curves. However, EFED generated 1989 pre-application, post-application, and Fall cumulative exceedence curves of atrazine, DEA, and DIA concentrations versus the % of sites with equal or greater concentrations. EFED also generated 1990 pre-application and post-application cumulative exceedence curves for those chemicals.

USGS 1990-1992 Study of 9 Mid-western Rivers/Streams (USGS Open-File Report 94-396):

The USGS sampled each of 9 mid-western rivers/streams several hundred times from April 1990 through July 1990. Samples were manually collected 1-2 times per week and automatically collected during runoff events either at several hour intervals or in response to changes in flows. During runoff events, 2-4 samples were typically collected at different times on the same day. The samples were analyzed for a number of pesticides including atrazine. Using the same sampling methodology in the Spring/Summer of 1991, the USGS collected additional samples from 2 of the 9 rivers/streams (the Iroquois River in IL and the Sangamon River in IL) from April 1991 through March 1992

The number of sites sampled (9) and the number of years sampled (1-2) were too low for EFED to generate cumulative exceedence curves from the data. However, EFED did generate two sets of atrazine time series curves from the data. In one set of atrazine time series curves, EFED plotted the average of the atrazine concentrations in all of the samples collected on the same day during a runoff event. In the other set of atrazine time series curves, EFED plotted the maximum atrazine concentration in all of the samples collected on the same day during a runoff event.

USGS April 1991 to September 1992 Study of the Mississippi River Basin (USGS Open-File Report 93-657):

The USGS sampled 8 sites within the Mississippi Basin from April 1991 through September 1992. Three of the sampling sites were on the Mississippi River. The other 5 sampling sites were on other rivers within the Mississippi Basin. Two samples were collected per week from May 6 to July 15, 1991. One sample was collected every two weeks from November 1991 through February 1992. One sample was collected per week during all other periods of the study (April 1991, July 15, 1991-October 30, 1991 and March 1992-July 1992). The samples were analyzed for a number of pesticides including atrazine.

The number of sites sampled (8) and the number of years sampled (1) were too low for EFED to generate cumulative exceedence curves from the data. However, EFED did generate atrazine time series curves from the data.

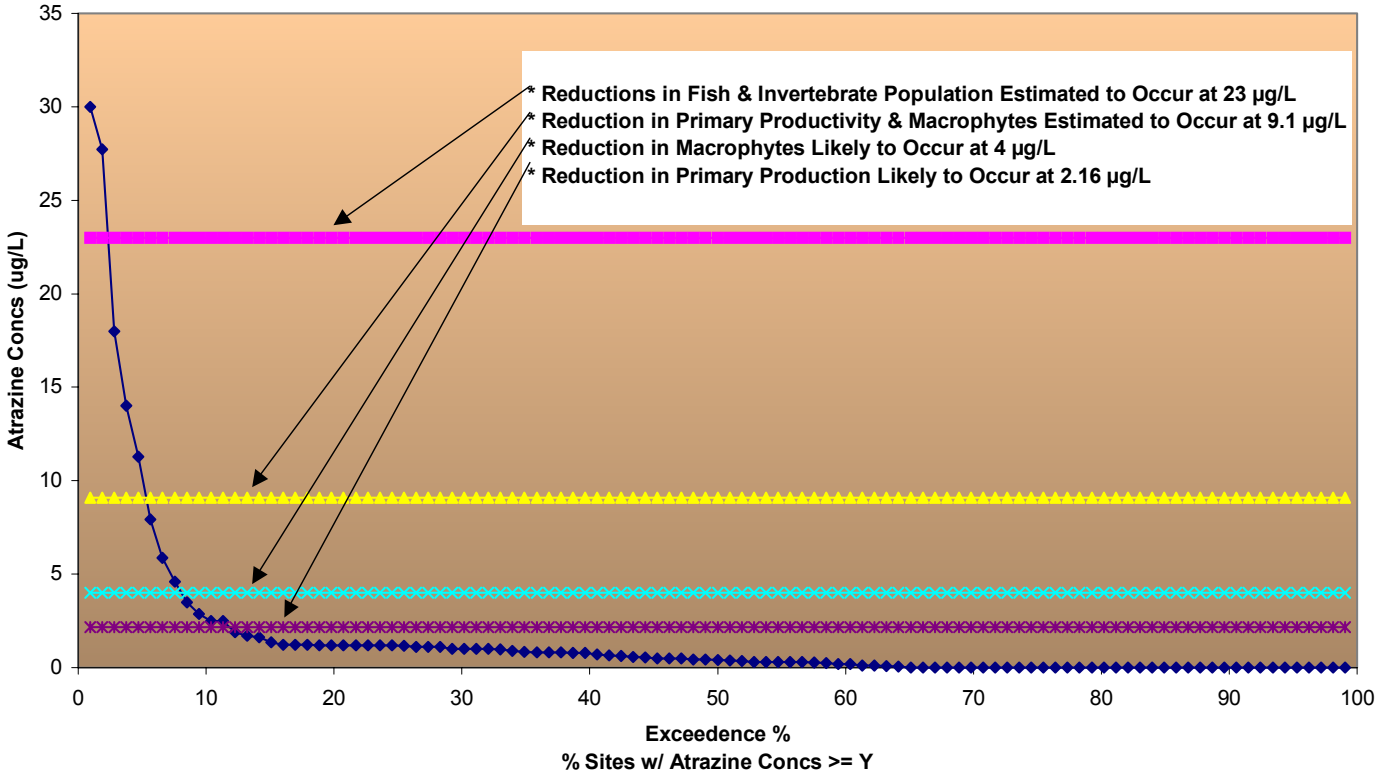
USGS 1994-1995 Reconnaissance Study of Mid-Western Streams (USGS Open-File Report 98-181):

In 1994, the USGS collected one "pre-application" sample, and one "post-application" sample from 52 and 50 mid-western streams, respectively, across 8 states. In 1995, the USGS collected one "post-application" sample from 50 mid-western streams across 7 states. "Pre-application" samples were generally collected in March or April before the applications of various herbicides. "Post-application" samples were collected during May or June during the first runoff event following the bulk of herbicide applications.

The samples were analyzed for a number of pesticides including atrazine, DEA, and DIA. The number of samples collected at each site (1-2 depending upon the site) was not adequate for EFED to generate atrazine, DEA, and DIA time series curves. However, EFED generated 1994 and 1990 pre-application and post-application cumulative exceedence curves of atrazine, DEA, and DIA concentrations versus the % of sites with equal or greater concentrations. EFED also generated 1995 post-application cumulative exceedence curves for those chemicals.

APPENDIX VIII. Chesapeake Bay Monitoring Data on Atrazine Levels

Figure 13. Surface Water Monitoring Results for Atrazine in the Chesapeake Bay's Tidal Rivers Maximxum Concentrations by Site and Year (1977 - 1993)



APPENDIX IX. Documentation of Terrestrial Fate Residue Model and Data

The model of Hoerger and Kenega (1972), as modified by Fletcher *et al.* (1994) was used to estimate pesticide concentrations on selected avian or mammalian food items. This model predicts the maximum concentrations that may occur immediately following a direct application at 1 lb ai/A. For 1 lb ai/A applications, peak concentrations (i.e., Day 0) on short grass, tall grass, broadleaf plants, and fruits are predicted to be as high as 240, 110, 135, and 15 ppm, respectively. The residue monitoring on which this model was based, did not include insects. However, based on similar surface area to volume ratio between insects and some plant parts, the predicted maximum concentration for broadleaf plants and fruits are used to represent maximum concentrations that may occur on small and large insects, respectively. Linear extrapolation is then used to estimate maximum terrestrial EEC's for single applications at application rates other than 1 lb ai/A. For example, a single application at 4 lbs ai/A would result in peak concentrations of 960 for short grass, 440 ppm for tall grass, 540 ppm for broadleaf foliage and small insects, and 60 ppm for fruits and large insects. If multiple applications are permitted, the peak terrestrial EECs resulting from subsequent applications are estimated by summing the maximum EEC predicted for the last application with the remaining concentrations predicted for the previous application(s). After application, residues on food items are predicted to decline according to a first order exponential model. If the maximum initial concentration is C_0 and the half-life for the exponential dissipation of the active ingredient is $t_{1/2}$, the remaining concentration at time t is given by the following formula:

$$C_t = C_0 e^{-\frac{t \ln 2}{t_{1/2}}}$$

The general formula for the peak EEC (C_{peak}) following multiple applications is:

$$C_{peak} = \sum_{i=1}^{n} C_0 e^{-\frac{I(n-1)\ln 2}{t_{1/2}}}$$

where C_0 is the maximum initial concentration after one application, I is the interval in days between applications, n is the number of applications, and $t_{1/2}$ is the half-life of the active ingredient.

The initial concentration, half-life, number of applications, interval between treatments, and length of simulation are variable. The current Fate Model has two limitations: 1) for more than two applications, only one time interval can be designated for a run; and 2) between treatments per fate run (i.e., two or more treatment intervals can not be used per run).
Four examples of Fate Model printouts follow; one each for short grass, foliage and small insects, long grass, and fruits, seeds and large insects.

The data tables used in the risk assessment for sugarcane, corn and sorghum are presented below.

DAILY PESTICIDE RESIDUE LEVELS ------ MAXIMUM. SUGARCANE USE RATE
SINGLE APPLICATION AT 4 LB AI./A ON SHORT GRASS

Chemical name ---------- Atrazine
Initial concentration (ppm) ---------- 960
Half-life ---------- 17
Length of simulated (day) ---------- 160

DAY	RESIDUE (PPM)	DAY	RESIDUE (PPM)	DAY	RESIDUE (PPM)
0	960	46	147.1362	92	22.5511
1	921.6448	47	141.2576	93	21.6501
2	884.822	48	135.6139	94	20.78511
3	849.4704	49	130.1957	95	19.95467
4	815.5313	50	124.9939	96	19.15742
5	782.9481	51	120	97	18.39.202
6	751.6668	52	115.2056	98	17.6572
7	721.6352	53	110.6027	99	16.95173
8	692.8035	54	106.1838	100	16.27446
9	665.1237	55	101.9414	101	15.62424
10	638.5498	56	97.8685	102	15
11	613.0376	57	93.95834	103	14.4007
12	588.5447	58	90.20439	104	13.82534
13	565.0304	59	86.60042	105	13.27297
14	542.4556	60	83.14045	106	12.74267
15	520.7826	61	79.81871	107	12.23356
16	499.9757	62	76.6297	108	11.74479
17	480	63	73.56808	109	11.27555
18	460.8224	64	70.62878	110	10.82505
19	442.411	65	67.80693	111	9.977337
20	424.7352	66	65.09783	112	9.578712
21	407.7656	67	62.49695	113	9.578712
22	391.4741	68	60	114	9.196009
23	375.8334	69	57.6028	115	8.828598
24	360.8176	70	55.30138	116	8.475866
25	346.4017	71	53.0919	117	8.137228
26	332.5618	72	50.9707	118	7.812118
27	319.2749	73	48. 93425	119	7.5
28	306.5188	74	46.97917	120	7.200348
29	294.2724	75	45.10219	121	6.91267
30	282.5152	76	43.3002	122	6.636485
31	271.2278	77	41.57022	123	6.371336
32	260.3913	78	39.90935	124	6.116781
33	249.9878	79	38.31484	125	5.872396
34	240	80	36.78403	126	5.637774
35	230.4112	81	35.31439	127	5.412525
36	221.2055	82	33.90347	128	5.196277
37	212.3676	83	32.54891	129	4.988669
38	203.8828	84	31.24847	130	4.789353
39	195.737	85	30	131	4.598002
40	187.9167	86	28.8014	132	4.414299
41	180.4088	87	27.65069	133	4.237933

42	173.2009	88	26.54595	134	4.068614
43	166.2809	89	25.48535	135	3.906059
44	159.6374	90	24.46713	136	3.75
45	153.2594	91	23.48958	137	3.600173
Maximum residue	----------			960	
Average residue	----------			149.0321	

DAILY PESTICIDE RESIDUE LEVELS ------ MAXIMUM. SUGARCANE USE RATE
SINGLE APPLICATION AT 4 LB AI./A ON BROADLEAF FOLIAGE

Chemical name ---------- Atrazine
Initial concentration (ppm) ---------- 540
Half-life ---------- 17
Length of simulated (day) ---------- 100

DAY	RESIDUE (PPM)	DAY	RESIDUE (PPM)	DAY	RESIDUE (PPM)
0	540	46	82.7641	92	12.68499
1	518.4252	47	79.45738	93	12.17818
2	497.7124	48	76.2828	94	11.69162
3	477.8271	49	73.23506	95	11.2245
4	458.7364	50	70.30907	96	10.77605
5	440.4084	51	67.5	97	10.34551
6	422.8126	52	64.80314	98	9.932172
7	405.9198	53	62.21404	99	9.53535
8	389.7019	54	59.72839	100	9.154381
9	374.1321	55	57.34204		
10	359.1842	56	55.05104		
11	344.8336	57	52.85157		
12	331.0564	58	50.73997		
13	317.8296	59	48.71274		
14	305.1313	60	46.7665		
15	292.9402	61	44.89802		
16	281.2363	62	43.1042		
17	270	63	41.38205		
18	259.2126	64	39.72869		
19	248.8562	65	38.1414		
20	238.9136	66	36.61753		
21	229.3682	67	35.15453		
22	220.2042	68	33.75		
23	211.4063	69	32.40157		
24	202.9599	70	31.10702		
25	194.851	71	29.86419		
26	187.066	72	28.67102		
27	179.5921	73	27.52552		
28	172.4168	74	26.42578		
29	165.5282	75	25.36998		
30	158.9148	76	24.35636		
31	152.5656	77	23.38325		
32	146.4701	78	22.44901		
33	140.6182	79	21.55209		
34	135	80	20.69102		
35	129.6063	81	19.86435		
36	124.4281	82	19.0707		
37	119.4568	83	18.30876		
38	114.6841	84	17.57727		
39	110.1021	85	16.875		
40	105.7031	86	16.20079		
41	101.4799	87	15.55351		
42	97.42548	88	14.9321		
43	93.53301	89	14.33551		
44	89.79606	90	13.76276		
45	86.20841	91	13.21289		

Maximum residue ---------- 540
Average residue ---------- 131.6416

DAILY PESTICIDE RESIDUE LEVELS ------ MAXIMUM. CORN & SORGHUM USE RATES
SINGLE APPLICATION AT 2 LB AI./A ON SHORT GRASS

Chemical name ---------- Atrazine
Initial concentration (ppm) ---------- 480
Half-life ---------- 17
Length of simulated (day) ---------- 100

DAY	RESIDUE (PPM)	DAY	RESIDUE (PPM)	DAY	RESIDUE (PPM)
0	480	46	73.56808	92	11.27555
1	460.8224	47	70.62878	93	10.82505
2	442.411	48	67.80693	94	10.39255
3	424.7353	49	65.09783	95	9.977337
4	407.7657	50	62.49695	96	9.578709
5	391.4741	51	60	97	9.196009
6	375.8334	52	57.60279	98	8.828598
7	360.8176	53	55.30137	99	8.475866
8	346.4017	54	53.0919	100	8.137228
9	332.5618	55	50.9707		
10	319.2749	56	48.93425		
11	306.5188	57	46.97917		
12	294.2724	58	45.1022		
13	282.5152	59	43.30022		
14	271.2278	60	41.57023		
15	260.3913	61	39.90936		
16	249.9878	62	38.31485		
17	240	63	36.78404		
18	230.4112	64	35.31439		
19	221.2055	65	33.90346		
20	212.3676	66	32.54891		
21	203.8828	67	31.24848		
22	195.737	68	30		
23	187.9167	69	28.8014		
24	180.4088	70	27.65069		
25	173.2009	71	26.54595		
26	166.2809	72	25.48535		
27	159.6374	73	24.46713		
28	153.2594	74	23.48958		
29	147.1362	75	22.5511		
30	141.2576	76	21.6501		
31	135.6139	77	20.78511		
32	130.1957	78	19.95467		
33	124.9939	79	19.15742		
34	120	80	18.39201		
35	115.2056	81	17.6572		
36	110.6028	82	16.95173		
37	106.1838	83	16.27446		
38	101.9414	84	15.62424		
39	97.8685	85	15		
40	93.95833	86	14.4007		
41	90.20439	87	13.82534		
42	86.60042	88	13.27298		
43	83.14046	89	12.74267		
44	79.81872	90	12.23356		
45	76.6297	91	11.74479		

Maximum residue ---------- 480
Average residue ---------- 117.0147

DAILY PESTICIDE RESIDUE LEVELS ------ MAXIMUM. CORN & SORGHUM USE RATES
SINGLE APPLICATION AT 2 LB AI./A ON BROADLEAF FOLIAGE

Chemical name ---------- Atrazine
Initial concentration (ppm) ---------- 270
Half-life ---------- 17
Length of simulated (day) ---------- 100

DAY	RESIDUE (PPM)	DAY	RESIDUE (PPM)	DAY	RESIDUE (PPM)
0	270	46	41.38205	92	6.342496
1	259.2126	47	39.72869	93	6.089091
2	248.8562	48	38.1414	94	5.845812
3	238.9136	49	36.61753	95	5.612252
4	229.3682	50	35.15453	96	5.388024
5	220.2042	51	33.75	97	5.172756
6	211.4063	52	32.40157	98	4.966087
7	202.9599	53	31.10702	99	4.767675
8	194.851	54	29.86419	100	4.577191
9	187.066	55	28.67102		
10	179.5921	56	27.52552		
11	172.4168	57	26.42578		
12	165.5282	58	25.36999		
13	158.9148	59	24.35637		
14	152.5656	60	23.38325		
15	146.4701	61	22.44901		
16	140.6182	62	21.5521		
17	135	63	19.86435		
18	129.6063	64	19.0707		
19	124.4281	65	18.30876		
20	119.4568	66	17.57727		
21	114.6841	67	16.875		
22	110.1021	68	16.20079		
23	105.7031	69	15.55351		
24	101.4799	70	14.9321		
25	97.42548	71	14.33551		
26	93.53301	72	13.76276		
27	89.79606	73	13.21289		
28	86.20841	74	13.21289		
29	82.7641	75	12.68499		
30	79.45739	76	12.17818		
31	76.28281	77	11.69162		
32	73.23506	78	11.2245		
33	70.30908	79	10.77605		
34	67.5	80	10.34551		
35	64.80315	81	9.932172		
36	62.21405	82	9.53535		
37	59.72839	83	9.154381		
38	57.34204	84	8.788632		
39	55.05104	85	8.4375		
40	52.85156	86	8.100393		
41	50.73997	87	7.776756		
42	48.71274	88	7.466048		
43	46.76651	89	7.167754		
44	44.89803	90	6.881379		
45	43.1042	91	6.606445		

Maximum residue ---------- 270
Average residue ---------- 65.8208

APPENDIX X. Terrestrial Plant Exposure Formulae

Calculating EECs for terrestrial plants inhabiting dry areas adjacent to treatment sites

Unincorporated ground application:
Runoff = maximum application rate (lbs ai/A) x runoff value
Drift = maximum application rate x 0.01
Total Loading = runoff (lbs ai/acre) + drift (lbs ai/A)

Incorporated ground application:
Runoff = [maximum application rate (lbs ai/A) ÷
minimum incorporation depth (cm.)] x runoff value
Drift = maximum application rate x 0.01
(Note: drift is not calculated if the product is incorporated at the time of application.)
Total Loading = runoff (lbs ai/A) + drift (lbs ai/A)

Aerial, airblast, forced-air, and chemigation applications:
Runoff = maximum application rate (lbs ai/A) x 0.6
(60% application efficiency assumed) x runoff value
Drift = maximum application rate (lbs ai/A) x 0.05
Total Loading = runoff (lbs ai/A) + drift (lbs ai/A)

Calculating EECs for terrestrial plants inhabiting semi-aquatic low-lying areas

Unincorporated ground application:
Runoff = maximum application rate (lbs ai/A) x runoff value x 10 acres
Drift = maximum application rate x 0.01
Total Loading = runoff (lbs ai/A) + drift (lbs ai/A)

Incorporated ground application:
Runoff = [maximum application rate (lbs
ai/A)/minimum incorporation depth (cm)] x runoff value x 10 acres
Drift = maximum application rate x 0.01
(Note: drift is not calculated if the product is incorporated at the time of application.)
Total Loading = runoff (lbs ai/A) + drift (lbs ai/A)

Aerial, airblast, and forced-air applications:
Runoff = maximum application rate (lbs ai/acre) x 0.6
(60% application efficiency assumed) x runoff value x 10 acres
Drift = maximum application rate (lbs ai/A) x 0.05
Total Loading = runoff (lbs ai/A) + drift (lbs ai/A)

Appendix XI. Ecological Effects Characterization

a. Toxicity to Terrestrial Animals

I. Birds, Acute and Subacute

An acute oral toxicity study using the technical grade of the active ingredient (TGAI) is required to establish the toxicity of atrazine to birds. The preferred test species is either mallard duck (a waterfowl) or bobwhite quail (an upland gamebird). Results of this test are tabulated below.

Avian Acute Oral Toxicity

Surrogate Species	% ai	LD50 (mg/kg) Probit Slope	Toxicity Category	MRID No. Author/Year	Study Classification[1]
Northern bobwhite quail (*Colinus virginianus*) 14-day old chicks; 8-day test	Tech.	940 slope 3.836	Slightly toxic	00024721 Fink 1976	Core
Mallard Duck (*Anas platyrhynchos*) 6-months old; 14-day test	76 % 80 WP	> 2,000 slope none	Practically non-toxic	00160000 Hudson, Tucker & Haegle 1984	Supplemental (only 3 birds) (formulation)
Ring-necked Pheasant (*Phasianus colchicus*) 3-months old; 14-day test	76 % 80 WP	> 2,000 slope none	Practically non-toxic	00160000 Hudson, Tucker & Haegle 1984	Supplemental (formulation)
Japanese Quail (*Coturnix c. japonica*) 50-60 days old; 14-day test	Tech.	4,237 slope > 6	Practically non-toxic	00024722 Sachsse and Ullman 1974	Supplemental (species not native)

[1] Core (study satisfies guideline). Supplemental (study is scientifically sound, but does not satisfy guideline)

Since the lowest LD_{50} is in the range of 501 to 2,000 mg/kg, atrazine is categorized as slightly toxic to avian species on an acute oral basis. According to Hudson *et al*. (1984), signs of intoxication in mallards first appeared 1 hour after treatment and persisted up to 11 days. In pheasants, remission of signs of intoxication occurred by 5 days after treatment. Signs of intoxication included weakness, hyper-excitability, ataxia, tremors; weight loss occurred in mallards. The guideline requirement (71-1) is fulfilled (MRID 00024721).

Degradates: The major atrazine degradate, hydroxyatrazine, forms a large percentage of the recoverable pesticide in various compartments of the environment. Minor atrazine degradates include deethylatrazine, deisopropylatrazine and diaminochlorotriazine. Acute mammalian LD_{50} values available for deethylatrazine and deisopropylatrazine are both more toxic than the parent atrazine. Therefore, a special (70-1) acute oral test with the upland gamebird (preferably northern bobwhite) are required to address the concern for these three degradates. The requirement (70-1) has not been fulfilled.

Two subacute dietary studies using the TGAI are required to establish the toxicity of atrazine to birds. The preferred test species are mallard duck and bobwhite quail. Results of these tests are tabulated below.

Avian Subacute Dietary Toxicity

Surrogate Species	% ai	5-Day LC50 (ppm)[1]	Toxicity Category	MRID No. Author/Year	Study Classification
Northern bobwhite (*Colinus virginianus*) 9-days old chicks	99.0	> 5,000 (no mortality)	Practically non-toxic	00022923 Hill *et al*. 1975	Core
Northern bobwhite (*Colinus virginianus*) young adults	Tech.	> 10,000	Practically non-toxic	unknown - Gulf South Gough & Shellenberger 1972	Supplemental (Adult birds & no raw data)
Ring-necked pheasant (*Phasianus colchicus*) 10-days old chicks	99.0	> 5,000 (no mortality)	Practically non-toxic	00022923 Hill *et al*. 1975	Core
Japanese Quail (*Coturnix c. japonica*) 7-days old chicks	99.0	> 5,000 (7 % mortality at 5,000 ppm)	Practically non-toxic	00022923 Hill *et al*. 1975	Supplemental (species not native)
Mallard duck (*Anas platyrhynchos*) 10-days old ducklings	99.0	> 5,000 (30 % mortality at 5,000 ppm)	Practically non-toxic	00022923 Hill *et al*. 1975	Core

[1] Test organisms observed an additional three days while on untreated feed.

Since the LC_{50} values are greater than 5,000 ppm, atrazine is categorized as practically non-toxic to avian species on a subacute dietary basis. The time to death was Day 3 for the one Japanese quail and Day 5 for three mallard ducks (J. Spann at Patuxent Wildlife Center, 1999, personal communication). The guideline requirement (71-2) is fulfilled (MRID 00022923).

Subacute dietary studies using a typical end-use product (TEP) may be required on a case-by-case basis to establish the toxicity of atrazine formulations to birds. The preferred test species are mallard duck and bobwhite quail. Results of these tests are tabulated below.

Formulation Avian Subacute Dietary Toxicity

Surrogate Species	% ai Form	5-Day LC50 (ppm ai)[1] Probit Slope	Toxicity Category	MRID No. Author/Year	Study Classification
Northern bobwhite (*Colinus virginianus*) (6-weeks old)	76 80 WP	5,760 slope 3.252	Practically non-toxic	00059214 Beliles & Scott 1965	Supplemental (birds too old)
Mallard duck (*Anas platyrhynchos*)	76 80 WP	19,560 slope 1.807	Practically non-toxic	00059214 Beliles & Scott 1965	Core for 80W formulation

[1] Test organisms observed an additional three days while on untreated feed.

Since the LC50 values are greater than 5,000 ppm, atrazine is categorized as practically non-toxic to avian species on a subacute dietary basis for the 80W formulation. In the mallard study, a highly noticeable weight loss and emaciated birds were found at all test levels (1,000 to

32,000). No additional data is required under guideline requirement 71-2 for atrazine formulations at this time.

Degradates: The major atrazine degradate, hydroxyatrazine, forms a large percentage of the recoverable pesticide in various environmental compartments. Acute mammalian LD_{50} values available for deethylatrazine and deisopropylatrazine, minor degradates, are both more toxic than the parent atrazine. Special (70-2) oral dietary tests for these degradates with waterfowl (preferably mallard duck) and upland gamebird (preferably northern bobwhite) are reserved pending the results of acute oral toxicity tests on these degradates. The requirement (70-2) is reserved.

ii. Birds, Chronic

Avian reproduction studies using the TGAI are required for atrazine, because the following conditions are met: (1) birds may be subject to repeated or continuous exposure to the pesticide, especially preceding or during the breeding season, (2) the pesticide is stable in the environment to the extent that potentially toxic amounts may persist in animal feed, (3) the pesticide is stored or accumulated in plant or animal tissues, and/or, (4) information derived from mammalian reproduction studies indicates reproduction in terrestrial vertebrates may be adversely affected by the anticipated use of the product. The preferred test species are mallard duck and bobwhite quail. Results of these tests are tabulated below.

Avian Reproduction

Surrogate Species/ Study Duration	% ai	NOEC/LOEC (ppm ai)	Statistically sign. (p=0.05) LOEC Endpoints	MRID No. Author/Year	Study Classification
Northern bobwhite (*Colinus virginianus*) 20 weeks	97.1	NOAEC 225 LOAEC 675	29 % red. in egg production 67 % incr. in defective eggs 27 % red. in embryo viability 6-13 % red. in hatchling body wt. 10-16 % red. in 14-day old body wt. 8.2 % red. in 14-day old body wt. (after recovery period)	42547102 Pedersen & DuCharme 1992	Core
		NOAEC < 75 LOAEC 75	6.7-18 % red. in 14-day old body wt.		
Mallard duck (*Anas platyrhynchos*) 20 weeks	97.1	NOAEC 225 LOAEC 675	49 % red. in egg production 61 % red. in egg hatchability 12-17 % red. in food consumption	42547101 Pedersen & DuCharme 1992	Core
		NOAEC 75 LOAEC 225	9-13 % red. in food consumption (During 3 of 11 biweekly periods)		

In the bobwhite study, the reproductive endpoints were measured after a 3-week recovery period. A statistically significant effect during the recovery period was a 700 percent increase in the number of defective eggs at 675 ppm compared to controls; the number of defective eggs was consistent with the number of defective eggs during the treatment period at 675 ppm. Bobwhite and mallard tests show similar toxic effects on reduced egg production and embryo viability/hatchability. In an 8-day LC_{50} test with adult Japanese quail, the quail fed atrazine had

reduced food consumption, lost body weight and egg production stopped after 3 days of exposure (Sachsse and Ullman, 1975; MRID 00024723). The guideline requirement (71-4) is fulfilled for both avian species (MRID 42547101, 42547102).

Degradates: The major atrazine degradate, hydroxyatrazine, forms a large percentage of the recoverable pesticide in various environmental compartments. Minor degradates were deethylatrazine, deisopropylatrazine and diaminochloro-s-triazine. Subchronic mammalian toxicity values available for deethylatrazine, deisopropylatrazine, hydroxyatrazine and diaminochlorotriazine indicate greater or equal toxicity compared to the parent atrazine in 10-day pregnancy tests, 13-week dog dietary tests, 1-year dog dietary tests and 2-year carcinogenicity tests. The requirement for avian reproductive tests with degradates are reserved pending the acute oral and dietary test results. The requirement (70-4) for degradates is reserved.

iii. Mammals, Acute

Wild mammal testing is required on a case-by-case basis, depending on the results of lower tier laboratory mammalian studies, intended use pattern and pertinent environmental fate characteristics. In most cases, rat or mouse toxicity values obtained from the Agency's Health Effects Division (HED) substitute for wild mammal testing. The acute toxicity values cited in HED's one-liners are reported below.

Mammalian Toxicity

Surrogate Species	% ai	Test Type	Toxicity Value	Affected Endpoints	MRID No./ Author
Laboratory mouse (*Mus musculus*)	??	Acute oral	1,750 mg/kg	LD50 (mortality)	Weed Sci. Assoc. 1967
Laboratory rat (*Rattus norvegicus*)	Tech.	Acute oral	1,869 mg/kg	LD50 (mortality)	00230303 Ciba-Geigy 1975
Laboratory rat (*Rattus norvegicus*)	Tech.	Acute oral	2,030 mg/kg	LD50 (mortality)	00231466 Instituto di Ricerche
Laboratory rat (*Rattus norvegicus*)	95	Acute oral	2,850 mg/kg	LD50 (mortality)	00027097 Consultox Lab. Ltd.
Laboratory rat (*Rattus norvegius*)	??	Acute oral	3,080 mg/kg	LD50 (mortality)	Weed Sci. Assoc. 1967
Laboratory mouse *(Mus musculus)*	Tech.	Acute oral	3,992 mg/kg	LD50 (mortality)	00230303 Ciba-Geigy 1977
FORMULATIONS:					
Laboratory rat (*Rattus norvegicus*)	85.5	Acute oral - female male	1,180 mg/kg 1,317 mg/kg	LD50 (mortality)	00249196 Stillmeadow Inc. 1980
Laboratory rat (*Rattus norvegicus*)	85.5 90 W	Acute oral	1,440 mg/kg	LD50 (mortality)	00000527 Industry Bio-Test 1971
Laboratory rat (*Rattus norvegicus*)	85.5	Acute oral	1,992 mg/kg	LD50 (mortality)	00000847 Hill Top Research, Inc.

Mammalian Toxicity

Surrogate Species	% ai	Test Type	Toxicity Value	Affected Endpoints	MRID No./ Author
Laboratory rat (*Rattus norvegicus*)	76 80 WP	Acute oral	>1,520 mg/kg <1,900 mg/kg	LD50 (mortality)	00046159 WIL Res. Lab. 1978
Laboratory rat (*Rattus norvegicus*)	76	Acute oral - male	2,147 mg/kg	LD50 (mortality)	00240852 Industrial Bio-Test 1974
Laboratory rat (*Rattus norvegicus*)	Atratol 8P	Acute oral	3,100 mg/kg (as product)	LD50 (mortality)	00234490 Food & Drug Res. 1977
Laboratory rat (*Rattus norvegicus*)	76 80 W	Acute oral	3,876 mg/kg	LD50 (mortality)	00230305 Industrial Bio-Test 1965
Laboratory rat (*Rattus norvegicus*)	51.0	Acute oral - female male	546 mg/kg 729 mg/kg	LD50 (mortality)	00245364 Food & Drug Res. Lab.
Laboratory rat (*Rattus norvegicus*)	44.3 Aatrex	Acute oral - female male	2,437 mg/kg 2,038 mg/kg	LD50 (mortality)	00000519 Not listed
Laboratory rat (*Rattus norvegicus*)	43 Flowable	Acute oral	830 mg/kg	LD50 (mortality)	00000522 Not listed
Laboratory rat (*Rattus norvegicus*)	42.0	Acute oral	811 mg/kg	LD50 (mortality)	00002041 Bio/Dynamics Inc. 1976
Laboratory rat (*Rattus norvegicus*)	40.8	Acute oral - female male	224 mg/kg 738 mg/kg	LD50 (mortality)	00242662 Raltech Sci. Serv. 1980
Laboratory rat (*Rattus norvegicus*)	40.8	Acute oral - female male	432 mg/kg 690 mg/kg	LD50 (mortality)	00000537 WIL Res. Lab. 1978
Laboratory rat (*Rattus norvegicus*)	40.8	Acute oral - female male	439 mg/kg 769 mg/kg	LD50 (mortality)	00246393 Toxigenics, Inc 1981
Laboratory rat (*Rattus norvegicus*)	40.8	Acute oral - female male	> 694 mg/kg 775 mg/kg	LD50 (mortality)	00243485 Cosmopolitan Safety Evalutation, Inc 1980
Laboratory rat (*Rattus norvegicus*)	40.8	Acute oral	1,306 mg/kg	LD50 (mortality)	00253726 Bio/Dynamics Inc. 1984
Laboratory rat (*Rattus norvegicus*)	40.8 Atrazine 4L	Acute oral - female male	1,918 mg/kg 1,705 mg/kg	LD50 (mortality)	00241725 Cosmopolitan Safety Evaluation, Inc

An analysis of the results indicate that atrazine and its formulations range from 224 to 3,992 mg/kg which categorized atrazine as moderately to slightly toxic to small mammals on an acute oral basis. Initial symptoms, piloerection and decreased activity, were reported as early as 30 minutes posttreatment. Other signs of toxicity include salivation, lacrimation, muscular weakness, tremor ataxia, diarrhea, adrenal degradation, congested lungs, and degeneration of kidneys and adrenal glands. Matching toxicity values for males and females in most cases (i.e., 7 out of 9 studies) indicate that females are more sensitive to atrazine than male rats. Atrazine does not appear to be dermally toxic to adult rats and rabbits; dermal LD50 values are greater than 2,000 mg/kg. Atrazine generally causes corneal opacity which clears by day 7. The need for mammalian acute toxicity is fulfilled.

Degradates: The major atrazine degradate, hydroxyatrazine, forms a large percentage of the recoverable pesticide in various compartments of the environment. Therefore, a special (70-3) acute oral test with small mammals is required to address degradate concerns.

Degradate Mammalian Acute Oral Toxicity

Surrogate Species/ Study Duration	% ai	Test Type	Toxicity Value	Affected Endpoints	MRID No.
Laboratory rat (*Rattus norvegicus*)	95.7 % Deethylatrazine (G-30033)	Acute oral - female male	668 mg/kg 1,881 mg/kg	LD50 (mortality) signs within 30 minutes died within 24-48 hours	43012302
Laboratory rat (*Rattus norvegicus*)	Tech. Deisopropylatrazine (G-28279)	Acute oral - female male	810 mg/kg 2,290 mg/kg	LD50 (mortality) signs within 0.5-48 hours died within 6-48 hours	43012301

Acute mammalian oral toxicity data are available for two degradates, deethylatrazine and deisopropylatrazine. The female LD_{50} values are more toxic to laboratory rats than technical grade values for the parent pesticide, atrazine. These degradates have LD_{50} values between 501 and 2,000 mg/kg which indicates that these degradates are slight toxicity orally. As with atrazine, the female toxicity values for the degradates indicate greater toxicity than for male rats. The requirement (71-3) for these two degradates are fulfilled, but the requirement (70-3) has not been fulfilled for the major degradate, hydroxyatrazine.

iv. Mammals, Chronic

Wild mammal reproduction testing is required on a case-by-case basis, depending on the results of lower tier laboratory mammalian studies, intended use pattern and pertinent environmental fate characteristics. Atrazine is persistent and initial residue levels exceed acute toxicity values. Usually mammalian chronic data are rat and/or mouse toxicity values are obtained from the Agency's Health Effects Division (HED) and substitute for wild mammalian testing. HED reproductive and systematic toxicity values are reported below.

Mammalian Subchronic and Reproduction Toxicity

Surrogate Species/ Study Duration	% ai	NOAEL/LOAEL (ppm ai)		Statistically sign. (p=0.05) LOEC Endpoints	MRID No. Author/Year	Study Classification
Laboratory Rat (*Rattus norvegicus*) 2-Generation Dietary	Tech.	NOAEL LOAEL NOAEL LOAEL	50 500 10 50	red. adult body weight and red. adult food consumption red. pup body weight in second generation	40431303 Ciba-Geigy 1987	Minimum
Laboratory Rat (*Rattus norvegicus*) 2-Yr Carcinogenicity	98.9	NOAEL LOAEL NOAEL LOAEL	10 70 70 500	incr. carcinomas for females (adenomas & fibroadenomas) red. mean adult body weight	00158930 American Biogenics Corp. 1986	Minimum
Laboratory Rat (*Rattus norvegicus*) 2-Yr Carcinogenicity	97	NOAEL LOAEL	70 400	red. adult body weight gain	42204401 Hazleton Lab. 1992	Minimum

Mammalian Subchronic and Reproduction Toxicity

Surrogate Species/ Study Duration	% ai	NOAEL/LOAEL (ppm ai)	Statistically sign. (p=0.05) LOEC Endpoints	MRID No. Author/Year	Study Classification
Laboratory Rat (*Rattus norvegicus*) Fed for 14 days	97.4	NOAEL 100 LOAEL 200	reduced estrogen levels	41570901 Hazelton Lab. 1990	Supplementary
Laboratory rat (*Rattus norvegicus*) Dosed on Days 6 - 15	97.4	NOAEL 100 LOAEL 500	increased fused sternebrae 1 & 2	43012308 Ciba-Geigy 1992	Guideline
Laboratory rat (*Rattus norvegicus*) Dosed on Days 6 - 15	95.7	NOAEL 100 LOAEL 500 NOAEL 500 LOAEL 2,000	17 % red. adult body weight gain incr. in fused sternebrae 1 & 2 incr. poor ossification of fifth toe	43013209 Ciba-Geigy 1992	Guideline
Laboratory rat (*Rattus norvegicus*) Dosed on Days 6-15 ?	96.7	NOAEL 200 LOAEL 1,400	red. body weight gain delayed ossification	40566301 Ciba-Geigy 1984	Minimum
Dog – Beagle (*Canis* sp.) 13-Week Feeding	Tech.	NOAEL < 200 LOAEL 200	red. body weight in males	00163339 WARF Institute 1997	Supplementary
Dog – Beagle (*Canis* sp.) 1-Year Feeding	97	NOAEL 150 LOAEL 1,000	increases in deaths, cachexia, ascite decr. body weight & food consumption irregular heart beat, incr. heart rate, incr. cardiac lesions	40431301 41293800 Ciba-Geigy 1987	Minimum
New Zealand Rabbit (L*epis* sp.)	96.3	NOAEL 33 LOAEL 165 NOAEL 165 LOAEL 2,475	red. body weight gain and red. food consumption. incr. resorptions, red. fetal body weights and delayed ossification of appendages	00143008 40566301 Ciba-Geigy 1984	Supplemental Minimum
Laboratory mice (*Mus musculus*) 22-Month Oncology	batch 84180 2	NOAEL 300 LOAEL 1,500	23.5 % red. male body weight 11 % red. female body weight incr. incidence of cardiac thrombi in females	40431302 Ciba-Geigy 1987	Guideline

The above mammalian chronic studies provide adequate toxicity data on chronic and reproductive effects. HED has concluded there is evidence that atrazine is associated with endocrine disruption. Direct measurements of norepinephrine, dopamine, and GnRH, and of serum hormones such as certain steroid hormones and luteinizing hormone, as well as changes in estrous cycling and histomorphic changes in hormone responsive tissues, indicate neuroendocrine disruption. The need for chronic mammalian toxicity data is fulfilled.

Degradates: The major atrazine degradate, 2-hydroxyatrazine, forms a large percentage of the recoverable pesticide in various environmental compartments. Several subchronic and chronic toxicity studies for atrazine degradates and/or metabolites are summarized in the table below for deethylatrazine, deisopropylatrazine, diaminochlorotriazine and hydroxyatrazine.

Degradate Mammalian Subchronic and Reproduction Toxicity

Surrogate Species/ Study Duration	% ai	NOAEL/LOAEL (ppm ai)	Statistically sign. (p=0.05) LOAEL Endpoints	MRID No. Author/Year	Study Classification
Laboratory rat (*Rattus norvegicus*) Fed for 14 days	assumed to be 98.2 Diaminochlorotriazine (G-28273)	NOAEL < 100 LOAEL 100 200	red. LH and prolactin levels red. estrogen, LH, prolactin and progesterone	41570901 Hazleton Lab. 1990	Supplemental
Laboratory rat (*Rattus norvegicus*) Diet for 13 weeks	95.7 Deethylatrazine (G-30033)	NOAEL 50 LOAEL 500	red. in female body weight red. in food efficiency for male and female rats	43012306 Ciba-Geigy 1991	Acceptable-Guideline
Laboratory rat (*Rattus norvegicus*) Diet for 13 weeks	96.7 Deisopropyltriazine (G-28279)	NOAEL 50 LOAEL 500	red. in body weights and red. body weight gains in males and females	43012305 Ciba-Geigy 1992	Core-Guideline
Laboratory rat (*Rattus norvegicus*) Diet for 13 weeks	98.2 Diaminochlorotriazine (G-28273)	NOAEL 10 LOAEL 100 NOAEL 100 LOAEL 250	Estrous cycle effects in female rats red. body weight gain in males and females Week 12	43012307 Ciba-Geigy 1991	Core-Guideline
Laboratory rat (*Rattus norvegicus*) Diet for 13 weeks	97.1 Hydroxyatrazine (G-34048)	NOAEL 100 LOAEL 300	renal effects - high urine output with low S.G. red. hematopoietic parameters in both sexes	41293501 Ciba-Geigy 1989	Minimum
Dog – Beagle (*Canis* sp.) 13-Week Feeding	95.7 Deethylatrazine (G-30033)	NOAEL 100 LOAEL 1,000	red. body weight & weight gain in males and females; red. heart to brain weight; normocytic/normochromic anemia, paroxysmal atrial fibrillation and right atrial wall hemorrhagic inflammation with angiomatous hyperplasia	43012304 Ciba-Geigy 1992	Core-Minimum
Dog -- Beagle (*Canis* sp.) 14-Week Feeding	96.7 Deisopropylatrazine (G-28279)	NOAEL 100 LOAEL 500	red. body weight, weight gain and food consumption in females red. organ to brain weight for heart, testes, prostrate glands in males	43012303 Ciba-Geigy 1992	Core-Minimum
Dog – Beagle (Canis sp.) 1-Year Feeding	98.7 Diaminochlorotriazine (G-28273)	NOAEL 5 LOAEL 100	1 of 8 females had tremors	41392401 Ciba-Geigy 1990	Minimum
Laboratory rat (*Rattus norvegicus*) Dosed on Days 6-15	95.7 Deethylatrazine (G-30033)	NOAEC 5 LOAEC 25 Development: NOAEL 25 LOAEC 100	red. body weight; weight gain and food consump. Fused sternebrae 1 & 2 Poor ossification of digit 5	43013209 Ciba-Geigy 1992	Acceptable-Guideline
Laboratory rat (*Rattus norvegicus*) Dosed on Days 6-15	97.4 Deisopropylatrazine (G-28279)	NOAEL 5 LOAEL 25 Development: NOAEL 5 LOAEL 25	red. maternal body weight, weight gain & food consumption fused sternebrae 1 and 2. poor ossification at 100 ppm	43012308 Ciba-Geigy 1992	Core - Guideline

Degradate Mammalian Subchronic and Reproduction Toxicity

Surrogate Species/ Study Duration	% ai	NOAEL/LOAEL (ppm ai)	Statistically sign. (p=0.05) LOAEL Endpoints	MRID No. Author/Year	Study Classification
Laboratory rat (*Rattus norvegicus*) Dosed on Days 6-15	98.2 Diaminochlorotriazine (G-28273)	NOAEL 500 LOAEL 3000 Development: NOAEL 50 LOAEC 500	red. body weight gain and food consumption incr. resorption of embryos incr. unossified bones	41392402 Ciba-Geigy 1989	Minimum
Laboratory rat (*Rattus norvegicus*) Dosed on Days 6-15	97.1 Hydroxyatrazine (G-34048)	NOAEL 500 LOAEL 2,500 Development: NOAEL 500 LOAEL 2500	decr. mother's food consumption red. young body weight incr. delay in ossification of skull bones	41065202 42873702 Ciba-Geigy 1989	Minimum
Laboratory rat (*Rattus norvegicus*) 2-yr Carcinogenicity	97.1 Hydroxyatrazine (G-34048)	NOAEL 10 LOAEL 25	incr. in accumulation of interstitial matrix in the kidney in females only	43532001 Ciba-Geigy 1995	Reserved
Laboratory rat (*Rattus norvegicus*) 2-yr Carcinogenicity	97.1 Hydroxyatrazine (G-34048)	NOAEL 25 LOAEL 200	incr. in urinary tract effects in both sexes	42662901 Ciba-Geigy 1993	Supplemental

Comparison of various subchronic and chronic toxicity levels for the following degradates (deethylatrazine, deisopropylatrazine, diaminochlorotriazine and hydroxyatrazine) with atrazine data suggest that the toxicity of these degradates are equal to or slightly more toxic to laboratory rats and beagles than atrazine. The degradate studies typically show similar types of toxic effects seen in atrazine tests. The mammalian chronic studies provide adequate data on chronic and reproductive effects of degradates.

v. Reptile Eggs

Atrazine was tested on eggs of the turtle, red-eared slider (*Pseudemys elegans*) and the American alligator (*Alligator mississippiensis*) to determine if atrazine produced endocrine effects on the sex of the young (Gross, 2001). The turtle and alligator eggs were placed in nests constructed of sphagnum moss treated with 0, 10, 50 100 and 500 μg/L for 10 days shortly after being laid. The test temperatures, 27.3°C for the turtle and 32.8° for alligators, were temperatures which normally yield all male young. No adverse effects were found. Analysis of the embryonic fluids indicated that no atrazine was present in the eggs at the detection limit (0.5 μg/L). Under these conditions, atrazine does not appear to be an endocrine disruptor. The non-guideline study is classified as supplemental and provides useful information on the potential effects of atrazine on endocrine-mediated pathways (MRID 455453-03 and 455453-02).

vi. Insects

A honey bee acute contact study using the TGAI is required for atrazine because its wide-spread use on corn and other crops that need insect pollination will result in honey bee exposure. Results of this test are tabulated below.

Nontarget Insect Acute Contact Toxicity

Surrogate Species	% ai	LD50 (μg/bee)	Toxicity Category	MRID No. Author/Year	Study Classification
Honey bee *(Apis mellifera)*	Tech.	96.69 (4.79% dead)	relatively non-toxic	00036935 Atkins *et al*. 1975	Core

Test results indicate that atrazine is categorized as relatively non-toxic to bees on an acute contact basis. The guideline (141-1) is fulfilled (MRID 00036935).

A honey bee toxicity of residues on foliage study using the typical end-use product is not required for atrazine because the acute contact honey bee LD50 is greater than 0.11 μg/bee. The guideline requirement (141-2) is fulfilled (MRID 00036935).

vii. Terrestrial Field Testing

No field tests have been required, because atrazine shows low toxicity to birds, mammals and insects.

b. Toxicity to Freshwater Animals

I. Freshwater Fish and Amphibia, Acute

Two freshwater fish toxicity studies using the TGAI are required to establish the toxicity of atrazine to fish. The preferred test species are rainbow trout (a coldwater fish) and bluegill sunfish (a warmwater fish). Results of these tests are tabulated below.

Freshwater Fish Acute Toxicity

Surrogate Species/ Static or Flow-through test	% a.i.	96-hour LC50 (ppb) (measured/nominal) Probit Slope	Toxicity Category	MRID No. Author/Year	Study Classification
Rainbow trout (*Oncorhynchus mykiss*) Static test	98.8	5,300 (nominal) slope - 2.723	moderately toxic	00024716 Beliles & Scott 1965	Core
Brook trout (*Salvelinus tontinalis*) Flow-through test	94	6,300 4,900 (8-day test) not specified	moderately toxic	00024377 Macek *et al*. 1976	Supplemental (52-gram fish & no raw data)
Fish from the Nile River *Chrysichthyes auratus* Static-renewal - daily 150 mg/L $CaCO_3$; 22°C	96	6,370 (not specified)	moderately toxic	45202911 Hussein, El-Nasser & Ahmed 1996	Supplemental (non-native sp.; 26-gram fish; no raw data)
Bluegill sunfish (*Lepomis macrochirus*) Flow-through test	94	> 8,000 6,700 (7-day test) (not specified)	moderately toxic	00024377 Macek *et al*. 1976	Supplemental (6.5-gram fish & no raw data)
Tilapia 38 grams (*Oreochromis niloticus*) Static-renewal - daily 150 mg/L $CaCO_3$: 22°C	96	9,370 (not specified)	moderately toxic	45202911 Hussein, El-Nasser & Ahmed 1996	Supplemental (non-native sp.; 38-gram fish; no raw data)

Freshwater Fish Acute Toxicity

Surrogate Species/ Static or Flow-through test	% a.i.	96-hour LC50 (ppb) (measured/nominal) Probit Slope	Toxicity Category	MRID No. Author/Year	Study Classification
Fathead minnow (*Pimephales promelas*) 24-Hour renewal test	94	15,000 (nominal) 15,000 (5-day test)	slightly toxic	00024377 Macek *et al*. 1976	Supplemental (no raw data)
Carp (*Cyprinus carpio*) Semi-static test	93.7	18,800 (nominal) slope not reported	slightly toxic	45202913 Neskovic *et al*. 1993	Supplemental (no raw data)
Fathead minnow juvenile (*Pimephales promelas*) Flow-through test; 52 mg/L $CaCO_3$	97.1	20,000 (measured) Slope - 6.889	slightly toxic	42547103 Dionne 1992	Core
Bluegill sunfish (*Lepomis macrochirus*) Static test	98.8	24,000 (nominal) no slope	slightly toxic	00024717 Beliles & Scott 1965	Core
Brown trout (*Salmo trutta*) 1.9 gr. Static-Renewal - daily pH 6; 10°C; 11 mg/L $CaCO_3$	??	27,000 (nominal)	slightly toxic	45202909 Grande, Anderson & Berge 1994	Supplemental (no raw data; slight aeration & purity unknown)
Zebrafish (*Brachydanio rerio*)	??	37,000 (???????)	slightly toxic	????????? Korte & Greim 1981	Supplemental (article unavailable)
Bluegill sunfish (*Lepomis macrochirus*) Static test	100	57,000 (nominal)	slightly toxic	00147125 Buccafusco 1976	Core
Goldfish (*Carassius auratus*) Static test	98.8	60,000 (nominal) Slope - 2.695	slightly toxic	00024718 Beliles & Scott 1965	Supplemental (not an acceptable species)

The lowest fish LC_{50} value falls in the range of > 1 - 10 ppm, hence atrazine is categorized as moderately toxic to freshwater fish on an acute basis. The guideline requirement (72-1) is fulfilled (MRID 00024716, 00024717, 000147125).

The following table presents fish toxicity data for formulated products.

Freshwater Fish and Amphibian Acute Toxicity

Surrogate Species/ Flow-through or Static	% ai formul.	96-hour LC50 (ppb) (measured/nominal)	Toxicity Category	MRID No. Author/Year	Study Classification
Black Bass - fry (*Micropterus salmoides*) Static test; 20°C 78 mg/L hardness	80 80 W	12,600 (nominal) slope - 5.86	slightly toxic	45227717 R. O. Jones 1962	Supplemental (48-hours; limited raw data)
Channel Catfish yolk sac (*Ictalurus punctatus*) Static test; 23.3-25.8°C 78 mg/L hardness	80 80 W	16,000 (nominal) slope - 3.36	sightly toxic	45227717 R. O. Jones 1962	Supplemental (limited raw data)

Freshwater Fish and Amphibian Acute Toxicity

Surrogate Species/ Flow-through or Static	% ai formul.	96-hour LC50 (ppb) (measured/nominal)	Toxicity Category	MRID No. Author/Year	Study Classification
Bluegill Sunfish fry (*Lepomis macrochirus*) Static test; 25-27°C 78 mg/L hardness	80 80 W	20,000 (nominal) no slope	slightly toxic	45227717 R. O. Jones 1962	Supplemental (limited raw data)
American Toad - larvae (*Bufo americanus*) Flow-through test	40.8 4L	10,700 late stage 26,500 early stage (nominal)	slightly toxic	45202910 Howe *et al*. 1998	Supplemental (no raw data)
Northern Leopard Frog larvae (*Rana pipiens*) Flow-through test	40.8 4L	14,500 late stage 47,600 early stage (nominal)	slightly toxic	45202910 Howe *et al*. 1998	Supplemental (no raw data)
Coho Salmon (*Oncorhynchus kisutch*) Renewal daily; 144 hr	40.8* AAtrex Liquid	> 18,000 25 % mortality (measured)	slightly toxic	45205107 Lorz *et al*. 1979	Supplemental (no LC_{50} value & 12-17 months old)
Rainbow trout (*Onchorhynchus mykiss*) Flow-through test	40.8 4L	20,500 (nominal)	slightly toxic	45202910 Howe *et al*. 1998	Supplemental (no raw data)
Channel Catfish (*Ictalurus punctatus*) Flow-through test	40.8 4L	23,800 (nominal)	slightly toxic	45202910 Howe *et al*. 1998	Supplemental (no raw data)
Rainbow trout (*Oncorhynchus mykiss*) Static test	43 Liquid	24,000 (unknown)	slightly toxic	40098001 Mayer & Ellersieck 1986	Supplemental (no raw data)
Bluegill sunfish (*Lepomis macrochirus*) Static test	43 Liquid	42,000 (unknown)	slightly toxic	40098001 Mayer & Ellersieck 1986	Supplemental (no raw data)

* Percent a.i. assumed based on description as a liquid formulation, AAtrex.

All toxicity values for the atrazine formulation are > 10 and 100 ppm, therefore this atrazine product is classified as slightly toxic.

Degradates: The major atrazine degradate, hydroxyatrazine, forms a large percentage of the recoverable pesticide in aquatic environmental compartments. Therefore, acute fish testing with bluegill and rainbow trout are required to address degradate concerns. The requirement for special degradate tests (72-1) has not been fulfilled.

ii. Freshwater Fish, Chronic

A freshwater fish early life-stage test using the TGAI is required for atrazine because the end-use product is expected to be transported to water from the intended use site, and the following conditions are met: the pesticide is intended for use such that its presence in water is likely to be continuous and recurrent; an aquatic acute EC50 is less than 1 mg/L (i.e., *Chironomus tentans* LC_{50} 0.72 ppm); and the pesticide is persistent in water (*i.e.*, half-life greater than 4 days). The preferred test species is rainbow trout.

Freshwater Fish Early Life Stage Toxicity

Surrogate Species/ Study Duration/ Flow-through or Static Renewal	% ai	NOAEC/LOAEC μg/L (ppb) (measured or nominal)	Statistically sign. (p=0.05) Endpoints Affected	MRID No. Author/Year	Study Classification
Rainbow trout (*Oncorhynchus mykiss*) 86 days, flow-through 50 mg/L $CaCO_3$	Tech.	NOAEC 410 LOAEC 1,100 (measured)	sign. delays in hatching @ 1,100 and 3,800 μg/L sign. red. wet wt. at 30 & 58 days @ 1,100 & 3,800 μg/L sign. red. dry wt. @ 3,800 μg/L 58.8 % mortality @ 3,800 μg/L at swim-up	45208304 Whale *et al*. 1994	Invalid (DMSO used as solvent, which aids in transport of chemicals across cell membranes)
Rainbow trout embryo-larvae (*Oncorhynchus mykiss*) 27 days; flow-through	80 WP	Hardness 50 mg/L: LC50 660 LC01 29 Slope 1.2 Hardness 200 mg/L: LC50 810 LC01 77 Slope 1.38	% normal survival 50/200 mg/L 19 μg/L - 94 98 54 - 88 90 54 ** - 68 74 5,020 ** - 10 9 50,900 ** - 0 0	45202902 Birge, Black & Bruser 1979	Supplemental (short test; no raw data for statistical analyses)
Channel catfish embryo-larvae (*Ictalurus punctatus*) 8 days; flow-through	80 WP	Hardness 50 mg/L: LC50 220 Slope 0.977 Hardness 200 mg/L: LC50 230 Slope 0.84	highly teratogenic in all tests; no results for soft water 420 μg/L - 16% terata 830 μg/L - 47 % terata 46,700 μg/L - 86 % terata	45202902 Birge, Black & Bruser 1979	Supplemental (short test; no raw data for statistical analyses)
Zebrafish (*Brachydanio rerio*) 35 Days; pH 8; 27$\pm$1 °C Flow-through test Hardness 24 mg/L	98	NOAEC 300 LOAEC 1,300 (measured) 35-Day LC50 890 Slope 1.25	2 - 3 % sign. incr. in edema 45-62 % mortality	45202908 Gorge & Nagel 1990	Supplemental (no raw data)

In addition to survival of rainbow trout and catfish embryo-larvae, Birge *et al*. (1979) also reported that "Atrazine was highly teratogenic in all tests." The frequency of teratogenicity was reported for channel catfish in hard water and included in the table above; no data on frequency was reported for soft water or for rainbow trout. (MRID # 45202902). The guideline requirement (72-4) for a fish early life stage test is fulfilled by four fish life-cycle tests with rainbow trout, bluegill and fathead minnows (listed below).

Degradates: The major atrazine degradate, hydroxyatrazine, forms a large percentage of the recoverable pesticide in aquatic environmental compartments. Therefore, a special fish early life-stage test (72-4) is reserved to address degradate concerns, pending the results of acute fish tests.

A freshwater fish life-cycle test using the TGAI is required for atrazine because the end-use product is expected to be transported to water from the intended use site and studies of other organisms indicate that the reproductive physiology of fish may be affected. The preferred test species is fathead minnow. Results of four fish life-cycle tests are tabulated below.

Freshwater Fish Life-Cycle Toxicity

Surrogate Species/ Study Duration/ Flow-through or Static Renewal	% ai	NOAEC/LOAEC µg/L (ppb) (measured or nominal)	Statistically sign. (p=0.05) Endpoints Affected	MRID No. Author/Year	Study Classification
Brook trout (*Salvelinus frontinalis*) 44 weeks, flow-through	94	NOAEC 65 LOAEC 120 (measured)	7.2 % red. mean length 16 % red. mean body weight	00024377 Macek *et al*. 1976	Core
Bluegill sunfish (*Lepomis macrochirus*) 6-18 months, flow-through	94	NOAEC 95 LOAEC 500 (measured)	LOAEC based on loss of equilibrium in a 28-day test conducted at the same lab.	00024377 Macek *et al*. 1976	Supplemental (Low survival in the controls)
Fathead minnow (*Pimephales promelas*) 39 weeks; flow-through	97.1	NOAEC < 150 LOAEC 150 (measured)	6.7 % red. in F_1 length 22 % red. in F_1 body wt. (sign. diff. from neg. control)	42547103 Dionne 1992	Supplemental (Failed to identify a NOAEC)
Fathead minnow (*Pimephales promelas*) 43 weeks, static-renewal	94	NOAEC 210 LOAEC 870 (measured)	LOAEC based on 25% mortality in a 96-hour test conducted at the same lab.	00024377 Macek *et al*. 1976	Supplemental (High mortality in control adults)

Moore and Waring (1998) report atrazine effects on reproductive endocrine function in mature male Atlantic salmon (*Salmo salar* L.) parr exposed to nominal concentrations of 0.5, 5, 10, and 20 µg/L, which were collected and measured at the end of the test. The measured levels are reported as 0.04, 3.6, 6.0 and 14.0 µg/L which are 8, 72, 60, and 70 percent of nominal, respectively. There appears to be uncertainty about the test concentrations, since the water samples were collected only after the test period and the authors concluded that atrazine in the water samples suffered rapid degradation as the result of an unavoidable delay in being analyzed. The guideline requirement (72-5) is fulfilled by the brook trout study (MRID 00024377).

Sublethal Effects:

Adult largemouth bass (*Micropterus salmoides*) were exposed to nominal concentrations of technical grade atrazine (purity 97.1%) at 0, 25, 35, 50, 75, and 100 µg/L for 20 days to determine the potential effects on endocrine function (Wieser and Gross, 2002) . Additionally, bass were exposed to commercial grade (purity 42.1%) atrazine at 100 µg/L. After 20 days, plasma concentrations of estradiol, 11-ketotestosterone, testosterone, and vitellogenin (a protein that serves in yolk formation) were measured.

Although the study concluded that atrazine treatment did not effect plasma steroid or vitellogenin levels, EFED believes that the study is confounded by the high level of variability in the test results. However, the results show that in spite of high levels of variability atrazine treatment significantly increased plasma estradiol in females and significantly decreased plasma 11-ketotestosterone in males. Additionally, although not statistically significant, vitellogenin levels in atrazine-treated female fish appeared to be elevated relative to controls. The presence of quantitative levels of plasma vitellogenin in male bass is of particular concern since the protein is normally only expressed in females; males can be induced to synthesize vitellogenin if exposed to an estrogenic compound.. Furthermore, the formulated endproduct appeared to

have enhanced effects on plasma steroids and vitellogenin levels relative to technical grade atrazine. These data further substantiate EFED's concerns regarding the endocrine disrupting potential of both technical grade atrazine and its formulated endproduct.

Previous studies examining the endocrine disrupting potential of both technical and commercial grade atrazine have shown that atrazine exposure increased plasma estradiol. Additionally, treatment with commercial atrazine increased plasma vitellogenin levels and decreased plasma testosterone levels at concentrations greater than 50 μg/ml (Gross *et al.* 1997; Grady *et al.* 1998). The current study was undertaken to examine more environmentally relevant doses and exposure routes. To that end, reproductively mature (approximately 2 year old) Florida strain largemouth bass were exposed to technical grade atrazine using a static renewal, no flow system at concentrations ranging from 0 to 100 μg/L and to commercial grade atrazine at 100 μg/L. After 20 days, plasma steroid and vitellogenin levels were measured. Vitellogenin has been recommended as a biomarker for measuring exposure to environmental estrogens since it is a sex-specific protein that is normally synthesized in yolk-producing females following its induction by estrogen; males fish do not typically synthesize vitellogenin unless exposed to an environmental estrogen.

In the current study, female bass treated with 100 μg/L formulated atrazine contained significantly higher plasma estradiol and exhibited plasma vitellogenin roughly 37 times greater (260 μg/ml) than controls (7 μg/ml). Male bass treated with 100 μg/L formulated atrazine contained significantly lower plasma 11-ketotestosterone. While not statistically significant, plasma testosterone (286 pg/ml) was lower than controls (433 pg/ml) and plasma vitellogenin (42 μg/ml) was 7 times greater than control (6 μg/ml). Although there was considerable variability in plasma vitellogenin levels, atrazine-treated fish appeared to have elevated plasma vitellogenin relative to controls. at 50 and 100 μg/L of atrazine. Plasma 11-ketotestosterone was significantly lower in fish exposed to atrazine concentrations greater than 35 μg/L. Treatment of fish with commercial grade atrazine resulted in a significant increase in plasma estradiol in female fish and a significant decrease in 11-ketotestosterone in male fish. Although not statistically significant, plasma vitellogenin in both female and male fish appeared to be increased in fish treated with technical and commercial grade atrazine.

Although high variability confounds this study's ability to resolve the effects of atrazine on plasma steroids and vitellogenesis, the study has demonstrated that technical grade atrazine affects plasma 11-ketotestosterone in males and that the formulated product affects plasma estradiol in females. The non-guideline study is classified as supplemental and provides useful information on the potential effects of atrazine on endocrine-mediated pathways. (MRID 45622304).

Three replicates of thirty, 4-day old African clawed frog tadpoles (*Xenopus laevis*) were exposed to each treatment at nominal concentrations of 0.01, 0.1, 1.0, 10.0 and 25 parts per billion (ppb) through metamorphosis (Hayes *et al*., 2002). Atrazine exposures had no effect on mortality, time to metamorphosis, length or weight at metamorphosis. Up to 20 percent (16 to

20%) of the male frogs exposed to $\geq$ 0.1 ppb atrazine had gonadal abnormalities including multiple testes and/or ovaries (no gonadal abnormalities occurred in controls).

Hayes *et al*. conducted a second experiment with atrazine tested nominal atrazine concentrations of 0.1, 0.4, 0.8, 1.0, 25 and 200 ppb. Control males had larger larynges than females at metamorphosis. In both studies, treated males had a threshold effect on reducing laryngeal diameters (demasculinized) at $\geq$ 1.0 ppb compared to controls. Kendall's rank coefficient suggested that a dose effect with increasing atrazine concentrations. ($p < 0.01$). Adult male and female *Xenopus* exposed to 25 ppb atrazine for 46 days suffered a 10-fold decrease in plasma testosterone. No raw data were available for statistical analyses.

Hayes *et al*. hypothesized that atrazine induces aromatase and promotes the conversion of testosterone to estrogen. This disruption in steroidogenesis via induction of aromatase are likely explanations for the 10-fold decrease in plasma testosterone, demasculinization of the male larynx and the production of hermaphrodites.

Hayes reported collection and analyses of leopard frogs (*Rana pipins*) at 7 sites in the west and mid-west states. One hundred frogs were collected at each site with about 50 percent males. In atrazine-treated areas in the mid-west states, 100 percent of the male leopard frogs had gonadal abnormalities. At the two sites in Utah where atrazine was not used, no gonadal abnormalities were found leopard frogs (personal communication - March 2002).

Syngenta in an oral presentation to the Atrazine working group provided the results from atrazine tests on the African clawed frog. There were no effects on the sex ratio of frogs exposed to atrazine concentrations of 0.01, 0.1, 1.0, 10 and 25 ppb during critical phases of development (undefined periods). The results of their study were reported as follows. "The ethanol solvent control exhibited significant activity on the frogs including effects on mortality, length, and development time. The possible confounding effect of ethanol within all treatments including atrazine is not known. There was no convincing evidence that atrazine increased the larynx cross-section area, although statistically significant differences were noted, especially in the 25 ppb group, and at high doses in various *ad hoc* tests performed. Unequal group sizes and other potential confounding study design elements further complicat interpretation. In addition, variability in the time course of frog ontogeny and potential tank effects, coupled with the lack of an 'estrogen' positive control group, prevented clear conclusions to be drawn from this preliminary study. Additional statistical analyses and studies are planned to further investigate these questions."

Thirty larval frogs per replicate and 3 replicates per treatment were exposed via test vessel solutions for approximately 60 days until metamorphosis was complete. Atrazine concentrations in the ethanol solution were 0.01, 0.1, 1.0 10.0 and 25 ppb and test solutions were renewed every three days. Analytical measurements of atrazine indicted recoveries ranging from 69 to 117 percent of nominal concentrations (no details were provided on the recoveries for each replicate at the beginning and end of the three day periods.

The information on the Syngenta study did not provide any raw data. It is obvious that the level of ethanol was too high because it caused mortality, growth effects. The ethanol concentration was not reported and the number of mortalities were not reported. When the solvent controls demonstrate these effects, the results of the study are compromised.

Atrazine effects on tadpoles are a concern, because atrazine use coincides with spring rains and the breeding season for amphibians. While these gonadal abnormalities and laryngeal alterations raise concerns about adverse effects on amphibian reproduction, there is no conclusive evidence that these changes have an adverse effect on amphibian reproduction. Additional testing with atrazine-treaded tadpoles and adult frogs should be conducted to determine what, if any, effects occur on reproduction.

Effects on behavior were found to be significant ($p < 0.0001$) in zebrafish (*Brachydanio rerio*) following 1-week exposures at 5 to 3125 μg/L atrazine (Steinberg *et al*., 1995). Fish exposed to atrazine for 1-week showed a pronounced preference ($p < 0.0001$) for the dark part of the aquarium compared to the control. Since no significant difference were found between the effects at the various test concentrations (5μg/L: 79%; 25μg/L: 85%; 125 μg/L: 83%; 625 μg/L: 81%; 3125 μg/L: 81%), these changes in swimming behavior appears to be threshold effects. After 4 weeks at the above exposures, 15 to 24 percent more of the treated fish preferred dark habitats than did the controls. The authors concluded that atrazine probably has an effect on the sensory organs and the nervous system at atrazine concentrations commonly found in surface waters. (MRID # 45204910).

Saglio and Trijase (1998) measured 5 behavioral activities in goldfish following 24-hour exposures to 0.5, 5 and 50 μg/L atrazine. A number of behavioral measurements were statistically significant ($p < 0.05$) from controls, but in most instances the significance was inconsistent and failed to show a dose-related effect. The only behavioral effect showing a consistent, dose-related effect was reduction in grouping (i.e., significant at 5 μg/L (31% reduction) and 50 μg/L (39% reduction). Other behaviors with statistically significant effects were surfacing at 5 μg/L (341% increase), burst swimming at 0.5 and 50 μg/L (1.00 and 2.25 units, respectively, the controls showed no effect). Following the introduction of skin extract, 5 μg/L of atrazine significantly ($p < 0.05$) reduced sheltering (81%) and grouping (60%), but these effects showed no consistency with effects at 0.5 and 50 μg/L. This study shows that a 24-hour exposure at 5 μg/L atrazine significantly affected aspects of swimming, positioning in water column, increased number of mouth openings at the surface, and social behaviors. (MRID # 45202914).

Fischer-Scherl *et al*. (1991) reported acute and chronic atrazine-induced alterations in the rainbow trout kidneys affecting renal corpuscles, renal tubules, and renal interstitium. Additionally, the accumulation of cellular debris in Bowman's space affects glomerular filtration. **Renal Corpuscles:** Compared to control fish, chronic 28-day exposures at 5, 10 and 20 μg/L almost obliterated Bowman's space due to a proliferation of podocytes with their epithelial foot processes forming tight and intensive connections. The most conspicuous feature was the thickening of the glomerular basement membrane, with formation of so-called spikes.

In some glomerula sub-endothelial humps, electron-dense deposits attached to glomerular basement membrane, have been detected. In some instances, moderate electron-dense material and membranous structures were deposited in Bowman's space. At higher chronic concentrations (40 and 80 μg/L) renal corpuscles appeared hypercellular and enlarged due to a proliferation of podocytes and mesangial cells. Also, the amount of membrane-bound vesicles with varying electron-dense contents had increased in the urinary space of renal corpuscles. Fibrillar structures and fibrocytes were found around Bowman's capsule indicating beginning periglomerular fibrosis. Acute 96-hour exposures at 1.4 and 2.8 mg/L caused a more pronounced obliteration of Bowman's space due to the proliferation of mesangial cells and more renal corpuscles were affected. Increasing amounts of cellular debris accumulated in Bowman's space. Simultaneously, epithelial cells of the parietal layer of Bowman's capsule displayed an increased number of lysosomes and swollen mitochondria. Also, the number of glomerular endothelial cells exhibiting vacuolar degeneration increased.
Renal Tubules: Light microscopy shows minor alterations to renal tubules, but electron micrographs revel considerable changes. First, obvious alterations of tubules appeared at 10 μg/L. Basilar labyrinth was dilated and irregularly arranged. The mitochondria were electron-dense and showed club-shaped ends of circular structure. At 40 μg/L, part of the endoplasmic reticulum appeared foamy and fragments of endoplasmic reticulum were heavily distended. At 80 μg/L in proximal and distal tubular epithelia lysis of the cytoplasm with formation of vacuoles and vesicles and condension of mitochondria was prominent. In many tubular epithelia, only remnants of the former parallel-arranged tubular system were present, mitochondria were swollen, lysosomal structures as well as a vacuolization of the cytoplasm were detectable. In proximal tubules, lysomes had increased in number and size. At acute exposures (1,400 and 2,800 μg/L), tubular structural lesions similar to those described at 80 μg/L were present, but a distinctly higher number of renal tubules was affected. Extensive cytoplasmic vacuolization was evident and the parallel arrangement of the basilar labyrinth was completely lost, some mitochondria were dark and condensed. Tubules of the basilar labyrinth appeared foggy, partly involving mitochondria.
Renal Interstitium: Except for an increase in cells with mitotic figures at concentrations of 5, 10, 20 μg/L, no conspicuous alterations in basic interstitial architecture could be detected. Beginning at 40 μg/L, a loosening of the hemopoietic tissue was evident. Cells, preumably macrophages, phagocytizing material had increased in number. In addition to these effects, sinusendothelial cells were severely damaged at a concentration of 80 μg/L. They separated from the basement membrane and exhibited numerous vesicular and lysosomal structures as well as swollen degenerating mitochondria. Alterations in renal interstitium were considerable at acute exposures with 1,400 and 2,800 μg/L. Interstitial tissue was loosened and a state of spongiosus was indicated. Numerous macrophages were present. Nuclei of interstitial cells were pyknotic or karyorhectic, mitochondria were swollen and the cytoplasm displayed lytic areas. Cell boundaries in some parts of the interstitium were lost. Cell organelles were scarce, but lysosomal structures abundant. (MRID # 45202907)

Davies *et al*. (1994) exposed three fish species to 0.9, 3.0, 10, 50 and 340 μg/L atrazine for a period of 10 days and measured effects on growth and properties of various tissues, such as blood, muscle and liver. Statistically significant ($p < 0.05$) effects occurred at levels as low as

0.9 and 3.0 μg/L. The most sensitive, consistent statistically significant effect was with the species *Galaxias maculatus* at 10 μg/L (i.e., 144% increase in muscle RNA/DNA levels), and the DNA levels were significantly reduced 25%. In *Pseudaphritis urvillii* consistent significant effects were found on glutathione (GSH) in the liver at 50 μg/L (24% reduction) and 340 μg/L (13% reduction). Consistent, significant effects with rainbow trout were found at 50 and 340 μg/L (i.e., reductions of 15% and 14%, respectively, in protein levels in muscle); and at 350 μg/L (159% reduction in growth and a 23% increase in glucose levels) (MRID # 45202904).

Alazemi *et al*. (1996) reported gill damage to a freshwater fish; the damage was characterized by the presence of breaks in the gill epithelium at 500 μg/L which developed into deep pits at 5,000 μg/L.

Hussein *et al*. (1996) exposed two important Rile River fish (*Oreochromis niloticus* and *Chrysichthyes auratus*) to 3,000 and 6,000 μg/L atrazine for up to 28 days. Fish exposed to these concentrations showed some clinical signs such as rapid respiration and increased rate of gill cover movements; slower reflexes and swimming movements; reduction in feeding activities; loss of equibrium and death. These signs were more pronounced in *C. auratus* than *O. niloticus*. About 25 percent of the treated fish had abdominal swelling (ascites) in the two species. Abnormal behavior could be attributed to the effect of atrazine on CNS and cardiovascular system. Exposure to 3,000 and 6,000 μg/L resulted in significant ($p < 0.01$) decreases in the number of red blood cells (RBC), hemoglobin and haematocrit levels compared to controls in both species. While the data appear to show clear differences from controls, these conclusions could not be verified from the data given in the article . The authors also reported significant ($p < 0.01$) changes in mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin (MCHC), serum components, and brain and serum AChE levels. While some of these measurements also appear to show clear differences between 3,000 and 6,000 μg/L and the controls, such as brain and serum AChE, whether the effects are significantly different than the controls could not be confirmed from the data presented in the article. (MRID # 45202911).

Neskovic *et al*. (1993) exposed carp to atrazine concentrations of 1,500, 3,000 and 6,000 μg/L and found biochemical changes in the activity of some enzyme activity levels in serum and some organs. Alkaline phosphatase levels were significantly ($p < 0.05$) higher in serum at all test levels than in controls. Alkaline phosphatase levels were lower, but not significantly ($p< 0.05$) less than control levels in the heart, liver and kidneys at all test levels. The greatest drop in alkaline phosphatase activity was found in the liver and ranged from 26.1% (1,500 μg/L) to 50.2% (6,000 μg/L). Somewhat weaker effects were found on glutamic-oxaloacetic (GOT) in the liver and kidney ($p < 0.1$). No statistically significant ($p < 0.01$) effects were found on glutamic-pyruvic transaminase (GPT). Histopathological effects include damage to gills ($\geq$ 1,500 μg/L), liver (almost normal at 1,500 μg/L and vacuolization of hepatocytes at $\geq$ 3,000 μg/L), kidney (more or less normal at 3,000 μg/L and with tubular epithelium and intertubular tissue degradation at 6,000 μg/L) and intestine (slightly greater lymphocyte infiltration and stronger mucous secretion at 6,000 μg/L) (MRID # 45202913).

iii. Freshwater Invertebrates, Acute

A freshwater aquatic invertebrate toxicity test using the TGAI is required to establish the toxicity of atrazine to aquatic invertebrates. The preferred test species is *Daphnia magna*. Results of this test and others are tabulated below.

Freshwater Invertebrate Acute Toxicity

Surrogate Species/ Static or Flow-through	% ai	96-hour LC50/EC50 μG/L (ppb) (measured/nominal) Probit Slope	Toxicity Category	MRID No. Author/Year	Study Classification
Midge (*Chironomus tentans*) Static test	94	720 (nominal)	highly toxic	00024377 Macek *et al*. 1976	Supplemental (48-hour LC50 & raw data are missing)
Midge (*Chironomus riparius*)	85.5	1,000 (unknown)	highly toxic	45087413 Johnson 1986	Supplemental (raw data are missing)
Waterflea (*Daphnia magna*)	85.5	3,500 (unknown)	moderately toxic	45087413 Johnson 1986	Supplemental (raw data are missing)
Waterflea < 24-hours old (*Daphnia magna*) 26-Hour static test	??	3,600 (unknown)	at least moderately toxic	00002875 Frear & Boyd 1967	Supplemental (unknown ai, 26-hour test & no raw data)
Waterflea (*Ceriodaphnia dubia*) 48-Hour static test	97	> 4,900 (measured) Slope - no mortality	unknown	45208309 Jop 1991	Supplemental (EC50 value not determined)
Scud (*Gammarus fasciatus*) Static test	94	5,700 (nominal)	moderately toxic	00024377 Macek *et al*. 1976	Supplemental (48-hour LC50 & raw data are missing)
Stonefly (nymph) (*Acroneuria* sp.) Flow-through test 67.4 mg/L $CaCO_3$	98.5	6,700 (measured)	moderately toxic	Brooke 1990	Supplemental (study not seen; OW in draft WQC)
Waterflea (*Daphnia magna*) Static test	94	6,900 (nominal)	moderately toxic	00024377 Macek *et al*. 1976	Supplemental (raw data are missing)
Scud juvenile (*Hyalella azteca*) Flow-through test 67.4 mg/L Ca CO_3	98.5	14,700 (measured)	slightly toxic	Brooke 1990	Supplemental (no study; cited by OW in draft WQC)
Scud juvenile (*Gammarus pulex*) Static-renewal - daily	??	14,900 (measured) 4.4 @ 10 days	slightly toxic	45202917 Taylor, Maund & Pascoe 1991	Supplemental (raw data are missing)
Leech (*Glossiphonia complanata*) Static-renewal weekly	99.2	> 16,000 (measured) 6,300 μg/L @ 28 days	slightly toxic	45202916 Streit & Peter 1978	Supplemental (raw data are missing)
Leech (*Helobdella stagnalis*) Static-renewal weekly	99.2	> 16,000 (measured) 9,900 μg/L @ 27 days	slightly toxic	45202916 Streit & Peter 1978	Supplemental (raw data are missing)

Freshwater Invertebrate Acute Toxicity					
Snail (*Ancylus fluviatilis*) Static-renewal weekly	99.2	>16,000 (measured) > 16, 000 μg/L @ 40 days (35 % mortality)	slightly toxic	45208305 Oris, Winner & Moore 1991	Supplemental (raw data are missing)
Waterflea <12 hr old (*Ceriodaphnia dubia*) Static 48-hour test 57 mg/L $CaCO_3$	> 99	> 30,000 (measured) Slope - no data	slightly toxic	45202917 Taylor, Maund & Pascoe 1991	Supplemental (raw data are missing)
Midge (*Chironomus riparius*) Static-renewal - daily 10-Day test	??	> 33,000 (measured) 18,900 μg/L @ 10 days	slightly toxic	00027204 Drake 1976	Supplemental (raw data are missing) (EC_{50} 115 ppm exceeds water solubility (33 ppm)
Formulations	% ai Product				
Waterflea (*Daphnia magna*) Flow-through test	79.6 80 WP	49,000 (higher concs. than 31,000 μg/L were cloudy) (measured) slope 2.433	slightly toxic	42041401 Putt 1991	Supplemental for formulation (EC_{50} was not identified due to insolubility)
Waterflea (*Daphnia pulex*) Static test; 15°C 282 mg/L hardness With & without sediment	40.8 4 L	36,500 (nominal) 46,500 (with sediment)	slightly toxic	45227712 Hartman & Martin 1985	Supplemental for formulation (EC50 exceeds water solublity and low temp.)

Since the lowest LC50/EC50 is in the range of 0.1 to 1 ppm, atrazine is categorized as highly toxic to aquatic invertebrates on an acute basis. The guideline requirement (72-2) is not fulfilled.

Degradates: The major atrazine degradate, hydroxyatrazine, forms a large percentage of the recoverable pesticide in aquatic compartments of the environment. Therefore, acute aquatic invertebrate testing with *Daphnia magna* is required to address degradate concerns. The requirement for the special degradate test (72-2) has not been fulfilled.

iv. Freshwater Invertebrate, Chronic

A freshwater aquatic invertebrate life-cycle test using the TGAI is required for atrazine since the end-use product is expected to be transported to water from the intended use site and the following conditions are met: the pesticide is intended for use such that its presence in water is likely to be continuous; an aquatic acute LC50 is less than 1 mg/L; and the pesticide is persistent in water (*i.e.*, half-life greater than 4 days). The preferred test species is *Daphnia magna*. Results of these tests are tabulated below.

Surrogate Species/ Study Duration/ Flow-through or Static Renewal	% ai	NOEC/LOEC µg/L (ppb) (measured or nominal)	Statistically sign. (p=0.05) Endpoints Affected	MRID No. Author/Year	Study Classification
Scud (*Gammarus fasciatus*) 30 days / flow-through	94	NOAEC 60 LOAEC 140 (measured)	25 % red. in development of F_1 to seventh instar.	00024377 Macek *et al*. 1976	Core
Midge (*Chironomus tentans*) 38 days / flow-through	94	NOAEC 110 LOAEC 230 (measured)	25 % red. in F_0 pupation 29 % red. in F_0 adult emergence 18 % red. in F_1 pupation 28 % red. in F_1 adult emergence	00024377 Macek *et al*. 1976	Core
Waterflea (*Daphnia magna*) 21 days / flow-through	94	NOAEC 140 LOAEC 250 (measured)	54 % red. in F_0 young/female	00024377 Macek *et al*. 1976	Core
Waterflea (*Daphnia pulex*) 28-Day static-renewal	99.2	NOAEC 1,000 LOAEC 2,000 (nominal)	16 % sign. red. in young/adult	45202915 Schober & Lampert 1977	Supplemental (no raw data for statistical analyses)
70-Day static-renewal test			31 % red. in young/adult		
Waterflea - 6 generations (*Daphnia magna*) Static-renewal test	??	Cups: NOAEC 200 LOAEC 2,000 (unknown) 4 L aquarium: NOAEC ?? LOAEC ?? (water from treated corrals)	66 % reduction in # of young in generations 4, 5, & 6. 72% reduction in # of young	Kaushik, Solomon, Stephenson and Day 1985	Supplemental (methods and raw data are not reported)
Leech (*Helobdella stagnalis*) 40 Days Static-Renewal weekly	99.2	NOAEC <1,000 LOAEC 1,000 (measured)	65% red. in percent hatch	45202916 Streit & Peter 1978	Supplemental (no raw data for statistical analyses)
Waterflea < 12 hr. old (*Ceriodaphnia dubia*) Two 7-Day static-renewal tests; Renewed M, W, & F 57 $CaCO_3$; Temp. 25°C	> 99	NOAEC 2,500 LOAEC 5,000 NOAEC 2,500 LOAEC 5,000 (measured)	sign. red. in mean total number of young per living female (3 broods)	45208305 Oris, Winner and Moore 1991	Supplemental (no raw data for analyses)
Green hydra (normal) (*Chlorohydra viridissima*) 21-Day Static test	??	NOAEC <5,000 LOAEC 5,000 (nominal)	sign. red. in budding rates	45202901 Benson & Boush 1983	Supplemental (no raw data for analyses)
Waterflea 3-day old adult (*Ceriodaphnia dubia*) Two 4-Day static-renewal tests; Renewed M & W 57 $CaCO_3$; Temp. 25°C	> 99	NOAEC 5,000 LOAEC 10,000 NOAEC 10,000 LOAEC 20,000 (measured)	sign. red. in mean total number of young per living female (3 broods)	45208305 Oris, Winner and Moore 1991	Supplemental (no raw data for analyses)
Freshwater Snail (*Ancylus fluviatilis*) 40 Days Static-Renewal weekly	99.2	1,000 4,000 16,000 (measured)	38-39% red. in egg capsules & eggs in April/May 56-57% red. in eggs in April/May 15-16% red. in eggs in July/Aug. 68-73% red. in eggs in April/May 65-71% red. in eggs in July/Aug.	45202916 Streit & Peter 1978	Supplemental (no raw data for statistical analyses)

Leech	99.2	1,000	no reduction in egg production	45202916	Supplemental
(*Glossiphonia complanata*)		4,000	17 % higher mortality	Streit & Peter	(no raw data
27-Days		16,000	33 % higher mortality	1978	for statistical
Static-Renewal weekly		(measured)	67 % higher mortality		analyses)

Growth stages and/or number of young are reduced by atrazine exposures for insects and crustaceans. The guideline requirement (72-4) is fulfilled (MRID 00024377).

Daphnia pulicaria was tested in a 12-day partial life cycle study to determine whether atrazine has an effect on the sex ratio (Madsen, 2000). No male *Daphnia* young were found at measured test concentrations 0, 0.93, 4.1, 8.7, 44, and 87 μg/L (MRID # 45299504).

Degradates: The major atrazine degradate is hydroxyatrazine which forms a large percent of the recoverable pesticide in aquatic compartments of the environment. Therefore, a special aquatic invertebrate life-cycle test (72-4) is reserved to address degradate concerns, pending the results of acute test.

v. Freshwater Field Studies

Walker (1964) treated Missouri ponds and plastic-lined limnocorrals with atrazine for aquatic weed control at levels of 500 to 2,000 μg/L and quantitatively examined effects on bottom organisms. Among the most sensitive organisms were mayflies (*Ephemeroptera*), caddis flies (*Tricoptera*), leeches (*Hirudinea*) and gastropods (*Musculium*). The most significant reduction in bottom fauna was observed during the period immediately following the application. Six to eight weeks after treatment, nine out of fourteen taxonomic groups had not recovered. The total number of bottom organisms per square foot was 52 percent lower than in the controls. In addition, three categories (water bugs, mosquitoes, and leeches) were no longer present. (MRID # 45202919).

Streit and Peter (1978) reviewed Walker's findings and investigated long-term atrazine effects on three benthic freshwater invertebrates: *Ancylus fluviatilis* (Gastropoda - Basommatophora), *Glossiphonia complanata* and *Helobdella stagnalis* (both: Annelida - Hirudinea) in the laboratory (see Chronic Invertebrate toxicity table). Ingestion rates for *G. complanata* were determined over a 27-day period at atrazine concentrations of 1, 4 and 16 ppm. The total ingestion per individual was measured daily (except between Day 23 and 27). Two significant results were: (1) Contaminated leeches ate significantly more limpets than the controls (300, 345 and 405% of control ingestion rates for 1,000, 4,000 and 16,000 μg/L atrazine exposures, respectively). (2) There was a constant feeding intensity from immediately after the beginning of the exposure period. The same phenomenon was seen for snails, *A. fluviatilis*, but the intensity of feeding was much less (i.e., 120, 130 and 140% of control ingestion rates at 1,000, 4,000 and 16,000 μg/L, respectively). Other observations included: (1) Leeches found sometimes lying on their backs suggesting that they have difficulty staying firmly attached to the substrate. (2) With increasing atrazine concentrations, an increasing percentage of snails could be detected that were just sucked out but not wholly eaten. Similar effects were observed

with the snails which suggest that leech and snail behavior might be affected in some way. Compared to controls, *Ancylus* egg production was significantly reduced after 40 days exposure to atrazine at 16,000 μg/L in March/April, April/May (68% fewer egg capsules and 73% fewer eggs) and July/August (65% fewer egg capsules and 71% fewer eggs). Lower *Ancylus* reproduction was also found at 4 μg/L in April/May (56-57 percent) and July/August (15-16 percent). At 1,000 μg/L, fewer capsules and eggs were found only in April/May (38 and 39 percent, respectively). The average number of eggs per brood in leech, *Glossiphonia complanata* was not affected by 27-days of atrazine exposure. The no significant effect was found on the number of live-born young of *Helobdella stagnalis*. At 1,000 and 4,000 μg/L only a part of the egg masses developed. Only about 10 percent of the young in the 16,000 μg/L treatment hatched. Atrazine did not affect the time for normal development (5-6 days). (MRID # 45202916).

Kettle *et al*. (1987) monitored effects of atrazine (40.8%) on diet and reproductive success of bluegill in experimental, Kansas ponds. The 0.045-hectare, 2.1-meter deep ponds were each stocked with adult fish (50 bluegills, 20 channel catfish and 7 gizzard shad). On July 24, atrazine was applied to two ponds at 20 μg/L, another two ponds at 500 μg/L and two controls. Atrazine concentrations were measured during the study and 70% of the original concentration was detected at the end of the 136-day study. Bluegills were the only species to spawn during the study. Atrazine had no significant effect on mortality of the original stocked fish, but the number of young bluegills retrieved were significantly ($p \leq 0.01$) reduced compared to control ponds (i.e., 95.7 % fewer in 20 μg/L-treated ponds and 96.1 % fewer in 500 μg/L-treated ponds). Stomach analyses of adult bluegills indicate that the bluegill controls had significantly ($p \leq 0.001$) higher numbers of food items per fish stomach and higher numbers of prey taxa per fish stomach. The number of food items per stomach were reduced 85 and 78 percent in 20 and 500 μg/L -treated ponds, respectively. Reductions in taxa per stomach were 57 and 52 percent in 20 and 500 μg/L-treated ponds, respectively. Stomachs of bluegills from treated ponds had fewer numbers of Ephemeroptera ($p \leq 0.001$), Odonata ($p \leq 0.001$), Coleoptera ($p \leq 0.01$) and Diptera (not significant, $p > 0.05$) than the controls. The macrophyte community in treated ponds was noticeably reduced, relative to controls, throughout the summer. Visual estimates of the macrophyte communities in the ponds showed roughly a 60 percent decline in the 20 μg/L ponds and a 90 percent decline in the 500 μg/L ponds two months after atrazine addition. These estimates were verified by rake hauls which produced these same relative differences. The following May, 10 months after treatment, when macrophytes are normally well established in Kansas ponds, the ponds were drained. Relative to control ponds, 20 μg/L ponds had a 90 percent reduction in macrophyte coverage and the 500 μg/L ponds had a >95 percent reduction in macrophyte coverage. Differences were noted in the macrophyte species present. Control ponds contained *Potamogeton pusillus* and *P. nodosus, Najas quadalupensis*, and small amounts of *Chara globularis*, whereas the treated ponds contained mostly *C. globularis.* (MRID # 45202912).

c. Toxicity to Estuarine and Marine Animals

i. Estuarine and Marine Fish, Acute

Acute toxicity testing with estuarine/marine fish using the TGAI is required for atrazine because the end-use product is expected to reach this environment because of its use in coastal counties. The preferred test species is sheepshead minnow. Results of these tests are tabulated below.

Estuarine/Marine Fish Acute Toxicity

Surrogate Species/ Static or Flow-through/ Salinity & Temperature	% ai	96-hour LC50 (ppb) (measured/nominal) Probit Slope	Toxicity Category	MRID No. Author/Year	Study Classification
Sheepshead Minnow larvae < 24-hours old (*Cyprinodon variegatus*) Static test, T - 20°C Salinity 25, 15, 5 g/L;	97.1	Sal. 25 g/L 2,000 Sal. 15 g/L 2,300 Sal. 5 g/L 16,200 (measured) Slope - no data	moderately toxic	45208303 & 45227711 Hall, Jr., Ziegenfuss, Anderson, Spittler & Leichtweis 1994	Supplemental (no raw data on mortalities)
Spot (*Leiostomus xanthurus*) Static test Salinity - 12 g/L; T - 22±1°C	97.4	8,500 (nominal) Slope - no data	moderately toxic	45202920 Ward & Ballantine 1985	Supplemental (no raw data)
Sheepshead minnow (*Cyprinodon variegatus*) Flow-through test Salinity - 31 g/L; T - 22-23°C	97.1	13,400 (measured) Slope 4.377	slightly toxic	43344901 Machado 1994	Core
Spot (juvenile) (*Leiostomus xanthurus*) Flow-through test Salinity - 29 g/L; T - 28°C	99.7	> 1,000 (nominal) Slope - none	unknown	40228401 Mayer 1986	Supplement (48-hour test)
Sheepshead minnow (*Cyprinodon variegatus*) Flow-through test	97.4	> 16,000 (30 % mortlity) (measured) Slope - none	unknown	45202920 Ward & Ballantine 1985	Supplemental (no raw data)

Since the LC50 are in the range of 1 - 10 ppm, Atrazine is categorized as moderately toxic to estuarine/marine fish on an acute basis. Toxicity data on sheepshead minnow, *Cyprinodon variegatus*, indicates that atrazine toxicity increases with increasing salinity levels. The pattern of increasing toxicity is opposite to atrazine toxicity data on the copepod, *Eurytemora affinis*. The guideline requirement (72-3a) is fulfilled (MRID 43344901).

Degradates: The major atrazine degradate, hydroxyatrazine, forms a large percentage of the recoverable pesticide in aquatic environmental compartments. Therefore, a special acute estuarine fish test (72-3) is required to address concerns for the toxicity of atrazine degradates to estuarine fish (preferably sheepshead minnow). The requirement (72-3) has not been fulfilled.

ii. Estuarine and Marine Fish, Chronic

An estuarine/marine fish early life-stage toxicity test using the TGAI is required for atrazine because the end-use product may be applied directly to the estuarine/marine environment or is expected to be transported to this environment from the intended use site, and the following

conditions are met: the pesticide is intended for use such that its presence in water is likely to be continuous; an aquatic acute LC50 or EC50 is less than 1 mg/L; and the pesticide is persistent in water (*i.e.*, half-life greater than 4 days). The preferred test species is sheepshead minnow. Results of this test are tabulated below.

Estuarine/Marine Fish Early Life-Stage Toxicity Under Flow-through Conditions

Surrogate Species/ Study Duration/ Flow-through or Static Salinity & Temperature	% ai	NOAEC/LOAEC μg/L (ppb) (measured or nominal)	Statistically sign. (p=0.05) Endpoints Affected	MRID No. Author/Year	Study Classification
Sheepshead Minnow (*Cyprinodon variegatus)* Study duration - unknown Flow-through test Salinity -13g/L; T 30±1°C	97.4	NOAEC 1,900 LOAEC 3,400 (measured)	89 % red. in juvenile survival	45202920 Ward & Ballantine 1985	Supplemental (no raw data for statistical analyses)

Biagianti-Risbourg and Bastide (1995) exposed juvenile gray mullets (*Liza ramada*) to 170 μg/L atrazine for 9, 20, and 29 days in static tests and for 11 days followed by 18 days of decontamination; and then measured the sublethal effects on the liver. At 170 μg/L, 10, 25 and 60 percent mortality occurred following 9-, 20- and 29-day exposures, respectively; control mortality was a constant 10 percent throughout the test. Treated mullets showed normal behavior until Day 20 after which they stopped feeding and rapidly died; which is in contrast to the 90 percent survival of the treated fish that were transferred to clean water after 11 days of exposure. After 3-days exposure, a number of abnormalities were found in the liver (i.e., hepatic parenchyma with a few cytologically detectable perturbations and hepatocytes had particularly large lipofuscin granules (MRID # 45204902). The guideline requirement (72-4) is not fulfilled since the study was lacking raw data and could not be evaluated.

Degradates: The major atrazine degradate, hydroxyatrazine, forms a large percentage of the recoverable pesticide in aquatic environmental compartments. Therefore, a special estuarine fish early life-stage test (72-4) is considered to address concerns for the toxicity of atrazine degradates to estuarine fish (preferably sheepshead minnow). The requirement (72-4) has not been fulfilled and is reserved pending the results of the acute estuarine fish test.

An estuarine/marine fish life-cycle test using the TGAI is reserved pending the results of acute and early life-stage tests on estuarine fish studies. The guideline requirements (72-5) is reserved.

iii. Estuarine and Marine Invertebrates, Acute

Acute toxicity testing with estuarine/marine invertebrates using the TGAI is required for atrazine because the end-use product is expected to reach this environment because of its use in coastal counties. The preferred test species are mysid shrimp and eastern oyster. Results of these tests are tabulated below.

Estuarine/Marine Invertebrate Acute Toxicity

Surrogate Species/ Static or Flow-through/ Salinity & Temperature	% ai.	96-hour LC50/EC50 μg/L (ppb) (measured/nominal) Probit Slope	Toxicity Category	MRID No. Author/Year	Study Classification
Copepod (*Acartia tonsa*) Static-renewal - daily Salinity - 31 g/L; T 22°C	70 Tech.	88 (measured) Slope 0.947	very highly toxic	45202918 Thursby *et al*. 1990 memo	Supplemental (12% control mortality)
Copepod (*Acartia tonsa*) Static test Salinity - 20 g/L; T 20±1°C	97.4	94 (nominal) Slope - none	very highly toxic	45202920 Ward & Ballantine 1985	Supplemental (no raw data)
Copepod (*Acartia tonsa*) Static-renewal - daily Salinity - 31-32 g/L; T 22°C	70 Tech.	139 (measured) Slope 0.543	highly toxic	45202918 Thursby *et al*. 1990 memo	Supplemental (20% control mortality)
Copepod nauplii < 24 hours old (*Eurytemora affinis*) Static test; T - 20°C Salinity - 5, 15 & 25g/L	97.1	Sal. 5 g/L 500 Sal. 15 g/L 2,600 Sal. 25 g/L 13,300 (measured) Slope - no data	highly toxic to slightly toxic	45208303 & 45227711 Hall, Ziegenfuss, Anderson, Spittler & Leichtweis 1994	Supplemental (no raw data on mortality)
Mysid Shrimp (*Americamysis bahia*) Flow-through test Salinity 26 g/L; T 22±1°C	97.4	1,000 (Measured) Slope - none	highly toxic	45202920 Ward & Ballantine 1985	Supplemental (no raw data)
Brown Shrimp (juvenile) (*Penaeus aztecus*) Flow-through test Salinity - 30 g/L; T 27°C	99.7	1,000 (nominal) Slope - none	at least highly toxic	40228401 Mayer 1986	Supplemental (48-hr LC_{50} & no raw data)
Copepod - 17 days old (*Acartia tonsa*) Flow-through test Salinity - 31-33 /L, T - 20°C	97.1	4,300 (measured) Slope - 2.467	moderately toxic	45208308 McNamara 1991	Supplemental (cloudy with no 0.45 μm filter of undissolved test material)
Mysid Shrimp (*Americamysis bahia*) Flow-through test Salinity -32 g/L; T 25-26°C	97.1	5,400 (measured) Slope 4.513	moderately toxic	43344902 Machado 1994	Core
Pink Shrimp (*Penaeus duorarum*) Static test Salinity 26 g/L; T 22±1°C	97.4	6,900 (nominal) Slope - none	moderately toxic	45202920 Ward & Ballantine 1985	Supplemental (no raw data)
Copepod (*Acartia clausii*) Static-renewal - daily Salinity - 31 g/L; T 6-6.2°C	70 Tech.	7,900 (nominal) Slope 0.958	moderately toxic	45202918 Thursby *et al*. 1990 memo	Core
Grass Shrimp (*Palaemonetes pugio*) Static test Salinity - 26 g/L; T 22±1°C	97.4	9,000 (nominal) Slope - none	Moderately toxic	45202920 Ward & Ballantine 1985	Supplemental (no raw data)
Eastern oyster (juvenile) (*Crassostrea virginica*) (Shell deposition) Flow-through test Salinity - 28 g/L; T - 28°C	99.7	> 1,000 no effect (nominal) Slope - none	unknown	40228401 Mayer 1986	Supplemental (EC_{50} has not been identified & no raw data)

Estuarine/Marine Invertebrate Acute Toxicity

Surrogate Species/ Static or Flow-through/ Salinity & Temperature	% ai.	96-hour LC50/EC50 μg/L (ppb) (measured/nominal) Probit Slope	Toxicity Category	MRID No. Author/Year	Study Classification
Mud Crab (*Neopanope texana*) Static test Salinity & T - unknown	Tech.	> 1,000 (nominal) Slope - none	slightly toxic	00024719 Bentley & Macek 1973	Supplemental (LC_{50} exceeds water solubility)

Since the lowest acute LC50/EC50 value is in the range of > 1 - 10 ppm, atrazine is categorized as moderately toxic to estuarine/marine invertebrates on an acute basis. Toxicity data on the copepod, *Eurytemora affinis*, indicates that atrazine toxicity decreases with increasing salinity levels. The pattern of decreasing toxicity is opposite to atrazine toxicity data on sheepshead minnows, *Cyprinodon variegatus*. The guideline requirement (72-3c) for shrimp is fulfilled (MRID 43344902), but the guideline requirement (72-3b) for oysters is not fulfilled.

Estuarine/Marine Invertebrate Acute Toxicity - Formulations

Surrogate Species/ Static or Flow-through	% ai. Product	96-hour LC50/EC50 μg/L (ppb) (measured/nominal) Probit Slope	Toxicity Category	MRID No. Author/Year	Study Classification
Eastern Oyster (*Crassostrea virginica*) (Shell deposition) Flow-through test Salinity -11.8 mg/L; T 21°C	79.6 80 WP	> 800 no effect (nominal) Slope - none	unknown	00024720 Wright & Beliles 1966	Supplemental (EC_{50} has not been identified)
Pacific Oyster (*Crassostrea gigas*) 24-Hour Static-Renewal	??	> 100 (nominal) 0.1 - 50% dead at 22 days 0.2 - 50% dead at 18 days	unknown	45227722 Moraga & Tanguy 2000	Supplemental (no 96-hour LC50 value)
European Brown Shrimp (*Crangon crangon*) Static test; 15°C	?? WP	10,000 - 33,000 (nominal) no slope	slightly toxic	45227728 Portmann 1972	Supplemental (only 48 hours & no raw data)
European Cockle (*Cardium edule*) Static test; 15°C	?? WP	> 100,000 (nominal) no slope	practically non-toxic	45227728 Portmann 1972	Supplemental (only 48 hours; LC_{50} exceeds water solubility & no raw data)
Fiddler Crab (*Uca pugilator*) Static test Salinity - 30 g/L; T 19°C	79.6 80 WP	198,000 (nominal) Slope - none	unknown	00024395 Union Carbide Corp. 1975	Supplemental (LC_{50} exceeds water solubility)
Fiddler Crab (*Uca pugilator*) Static test Salinity - 30 g/L; T 19°C	Unknown 4-1-3-1 WDL	239,000 (nominal) Slope - none	unknown	00024395 Union Carbide Corp. 1975	Supplemental (LC_{50} exceeds water solubility)

The toxicity of formulated atrazine products to marine/estuarine invertebrates are uncertain, because the EC/LC_{50} values are not definitive.

Degradates: The major atrazine degradate, hydroxyatrazine, forms a large percentage of the recoverable pesticide in aquatic environmental compartments. Therefore, estuarine invertebrate acute tests (72-3b and c) are required to address concerns for the toxicity of atrazine degradates to estuarine invertebrates (preferably *Americamysis bahia* and *Crassostrea virginica*). The requirement (72-3b and c) have not been fulfilled for any atrazine degradate.

iv. Estuarine and Marine Invertebrate, Chronic

An estuarine/marine invertebrate life-cycle toxicity test using the TGAI is required for atrazine because the end-use product may be applied directly to the estuarine/marine environment or is expected to be transported to this environment from the intended use site, and the following conditions are met: the pesticide is intended for use such that its presence in water is likely to be continuous and recurrent; an aquatic acute EC_{50} is less than 1 mg/L; and the pesticide is persistent in water (*e.g.*, half-life greater than 4 days). The preferred test species is mysid shrimp. Results of this test are tabulated below.

Estuarine/Marine Invertebrate Life-Cycle Toxicity

Species/ Duration/ Flow-through/ Static-renewal	% ai	NOAEC/LOAEC µg/L (ppb) (measured/nominal)	Statistically sign. (P=0.05) Endpoints Affected	MRID No. Author/Year	Study Classification
Mysid *(Americamysis bahia)* Duration of test - unknown Flow-though test Salinity 20 g/L; 25±1°C	97.4	NOAEC 80 LOAEC 190 (measured)	37 % red. in adult survival	45202920 Ward & Ballantine 1985	Supplemental (no raw data for statistical analyses)

The guideline requirement (72-4b) for an estuarine invertebrate life-cycle test is not fulfilled.

Degradates: The major atrazine degradate, hydroxyatrazine, forms a large percentage of the recoverable pesticide in aquatic environmental compartments. Therefore, a special estuarine invertebrate life-cycle test (72-3) is required to address concerns for the toxicity of atrazine degradates to estuarine invertebrates (preferably *Americamysis bahia*). The requirement (72-4b) has not been fulfilled for any atrazine degradate, but is reserved pending the results of the acute mysid test.

v. Estuarine and Marine Field Studies

Field studies are not available with atrazine effects on estuarine and/or marine animals. No estuarine field studies are required.

d. Toxicity to Plants

I. Terrestrial

Terrestrial plant testing (seedling emergence and vegetative vigor) is required for herbicides that have terrestrial non-residential outdoor use patterns and that may move off the application site through volatilization (vapor pressure >1.0 x 10^{-5}mm Hg at 25ºC) or drift (aerial or irrigation) and/or that may have endangered or threatened plant species associated with the application site.

For seedling emergence and vegetative vigor testing the following plant species and groups should be tested: (1) six species of at least four dicotyledonous families, one species of which is soybean (*Glycine max*) and the second is a root crop, and (2) four species of at least two monocotyledonous families, one of which is corn (*Zea mays*).

Terrestrial Tier II studies are required for all herbicides and any pesticide showing a negative response equal to or greater than 25% in Tier I tests. Tier II tests measure the response of plants, relative to a control, and five or more test concentrations at a test level that is equal to the highest use rate (expressed as lbs ai/A). Results of Tier II toxicity testing on the technical material are tabulated below.

Nontarget Terrestrial Plant Seedling Germination Toxicity (Tier II)

Surrogate Species	% ai	EC25/EC05 (lbs ai/A) Probit Slope	Endpoint Affected	MRID No. Author/Year	Study Classification
Monocot - Corn (*Zea mays*)	97.7	< 4.0 / < 4.0	No effect	41223001 Chetram 1989	Core
Monocot - Oat (*Avena sativa*)	97.7	1.8 / 0.12 slope 0.834	% red..in radicle length	41223001 Chetram 1989	Core
Monocot - Onion (*Allium cepa*)	97.7	< 4.0 /< 4.0	No effect	41223001 Chetram 1989	Core
Monocot - Ryegrass (*Lolium perenne*)	97.7	< 4.0 / < 4.0 slope 0.834	No effect	41223001 Chetram 1989	Core
Dicot - Root Crop - Carrot (*Daucus carota*)	97.7	<4.0 / < 4.0	No effect	41223001 Chetram 1989	Core
Dicot - Soybean (*Glycine max*)	97.7	< 4.0 / < 4.0	No effect	41223001 Chetram 1989	Core
Dicot - Lettuce (*Lactuca sativa*)	97.7	< 4.0 / < 4.0	No effect	41223001 Chetram 1989	Core
Dicot - Cabbage (*Brassica oleracea alba*)	97.7	< 4.0 / < 4.0	No effect	41223001 Chetram 1989	Core
Dicot - Tomato (*Lycopersicon esculentum*)	97.7	< 4.0 / < 4.0	No effect	41223001 Chetram 1989	Core
Dicot - Cucumber (*Cucumis sativus*)	97.7	0.80 / 0.60 slope 0.864	% red. in radicle length	41223001 Chetram 1989	Core

Results from the Tier II seedling germination tests indicate that cucumber is the most sensitive dicot and oats is the most sensitive monocot. These studies are acceptable (MRID 41223001), but the guideline requirement for seed germination testing has now been included in the seedling emergence toxicity test.

Nontarget Terrestrial Plant Seedling Emergence Toxicity (Tier II)

Surrogate Species	% ai	EC25 / NOAEC (lbs ai/A) Probit Slope	Endpoint Affected	MRID No. Author/Year	Study Classification
Monocot - Corn (*Zea mays*)	97.7	< 4.0 / < 4.0	No effect	42041403 Chetram 1989	Core
Monocot - Oat (*Avena sativa*)	97.7	0.004 / 0.0025	red. in dry weight	42041403 Chetram 1989	Core
Monocot - Onion (*Allium cepa*)	97.7	0.009 / 0.005	red. in dry weight	42041403 Chetram 1989	Core
Monocot - Ryegrass (*Lolium perenne*)	97.7	0.004 / 0.005	red. in dry weight	42041403 Chetram 1989	Core
Dicot - Root Crop - Carrot (*Daucus carota*)	97.7	0.003 / 0.0025	red. in dry weight	42041403 Chetram 1989	Core
Dicot - Soybean (*Glycine max*)	97.7	0.19 / 0.025	red. in dry weight	42041403 Chetram 1989	Core
Dicot - Lettuce (*Lactuca sativa*)	97.7	0.005 / 0.005	red. in dry weight	42041403 Chetram 1989	Core
Dicot - Cabbage (*Brassica oleracea alba*)	97.7	0.014 / 0.01	red. in dry weight	42041403 Chetram 1989	Core
Dicot - Tomato (*Lycopersicon esculentum*)	97.7	0.034 / 0.01	red. in dry weight	42041403 Chetram 1989	Core
Dicot - Cucumber (*Cucumis sativus*)	97.7	0.013 / 0.005	red. in dry weight	42041403 Chetram 1989	Core

For Tier II seedling emergence, the most sensitive dicot is the carrot and the most sensitive monocots are oat and ryegrass. The guideline requirement (123-1a) is fulfilled (MRID 42041403).

Nontarget Terrestrial Plant Vegetative Vigor Toxicity (Tier II)

Surrogate Species	% ai	EC25 / NOAEC (lbs ai/A)	Endpoint Affected	MRID No. Author/Year	Study Classification
Monocot - Corn (*Zea mays*)	97.7	< 4.0 / < 4.0	No effect	42041403 Chetram 1989	Core
Monocot - Oat (*Avena sativa*)	97.7	2.4 / 2.0	red. in dry weight	42041403 Chetram 1989	Core
Monocot - Onion (*Allium cepa*)	97.7	0.61 / 0.5	red. in dry weight	42041403 Chetram 1989	Core
Monocot - Ryegrass (*Lolium perenne*)	97.7	< 4.0 / < 4.0	No effect	42041403 Chetram 1989	Core
Dicot - Root Crop - Carrot (*Daucus carota*)	97.7	1.7 / 2.0	red. in plant height	42041403 Chetram 1989	Core
Dicot - Soybean (*Glycine max*)	97.7	0.026 / 0.02	red. in dry weight	42041403 Chetram 1989	Core
Dicot - Lettuce (*Lactuca sativa*)	97.7	0.33 / 0.25	red. in dry weight	42041403 Chetram 1989	Core

Nontarget Terrestrial Plant Vegetative Vigor Toxicity (Tier II)

Surrogate Species	% ai	EC25 / NOAEC (lbs ai/A)	Endpoint Affected	MRID No. Author/Year	Study Classification
Dicot - Cabbage (*Brassica oleracea alba*)	97.7	0.014 / 0.005	red. in dry weight	42041403 Chetram 1989	Core
Dicot - Tomato (*Lycopersicon esculentum*)	97.7	0.72 / 0.5	red. in plant height	42041403 Chetram 1989	Core
Dicot - Cucumber (*Cucumis sativus*)	97.7	0.008 / 0.005	red. in dry weight	42041403 Chetram 1989	Core

For Tier II vegetative vigor, the most sensitive dicot is cucumber and the most sensitive monocot is onion. The guideline requirement (123-1b) is fulfilled (MRID 42041402).

ii. Aquatic Plants

Aquatic plant testing is required for any herbicide that has outdoor non-residential terrestrial uses that may move off-site by runoff (solubility >10 ppm in water), by drift (aerial or irrigation), or that is applied directly to aquatic use sites (except residential). Aquatic Tier II studies are required for all herbicides and any pesticide showing a negative response equal to or greater than 50% in Tier I tests. The following species should be tested at Tier II: *Kirchneria subcapitata*, *Lemna gibba*, *Skeletonema costatum*, *Anabaena flos-aquae*, and a freshwater diatom. Aquatic plant testing is required for atrazine because atrazine is applied on crops outdoors and would appear to be mobile with a water solubility value of 33 ppm.

Results of Tier II toxicity testing on technical grade and typical end-use products (TEP) are tabulated below. The data are presented in four toxicity tables separating the freshwater data from the marine data and the short, 7-day or less tests from the longer tests.

Nontarget Freshwater Plant Toxicity (Tier II)

Surrogate Species/ Duration/Measured/nominal	% ai	Conc. (ppb) Probit Slope	% Response	MRID No. Author/Year	Study Classification
Vascular Plants:					
Duckweed (*Lemna gibba*) 5-Day test; Static-Renewal	97	170 (nominal) Slope 3.93	50% red. in growth	41065203d Hughes 1986	Supplemental (5 days, not 14 days)
Duckweed (*Lemna gibba*) 7-Day test; Static-Renewal	97	170 (measured) Slope 2.2	50% red. in growth	42041404 Hoberg 1991	Supplemental (7 days, not 14 days)
Non-Vascular Plants:					
Cyanophyceae *Oscillatoria lutea* (1week; nominal)	76 80 W	< 1 1,000	93% red. chlorophyll production 100% red. chlorophyll prod.	Torres and O'Flaherty 1976	Supplemental (raw data unavailable)

Nontarget Freshwater Plant Toxicity (Tier II)

Surrogate Species/ Duration/Measured/nominal	% ai	Conc. (ppb) Probit Slope	% Response	MRID No. Author/Year	Study Classification
Chlorophyceae *Stigeoclonium tenue* (1 week; nominal)	76 80 W	< 1 1,000	67% red. chlorophyll production 90% red. chlorophyll production	Torres and O'Flaherty 1976	Supplemental (raw data unavailable)
Green Algae - Chlorophyceae *Chlorella vulgaris* (1 week; nominal)	76 80 W	1 1,000	50% red. chlorophyll production 80-87% red. chlorophyll production	Torres and O'Flaherty 1976	Supplemental (raw data unavailable)
Xanthophyceae *Tribonema* sp. (1 week; nominal)	76 80 W	1 1,000	42% red. chlorophyll production 75% red. chlorophyll production	Torres and O'Flaherty 1976	Supplemental (raw data unavailable)
Xanthophyceae *Vaucheria geminata* (1 week; nominal)	76 80 W	1 1,000	41% red. chlorophyll production 100% red. chlorophyll production	Torres and O'Flaherty 1976	Supplemental (raw data unavailable)
Chlorophyceae *Chlamydomonas reinhardi* (24 hour; nominal)	Unk.	19 44 48	50% red. carbon uptake; media: Taub & Dollar (TD)	45020015 Larsen *et al*. 1986	Supplemental (raw data unavailable)
Chlorophyceae *Kirchneria subcapitata* *=Selenastrum capricornutum* (96 hours; nominal)	Tech.	26 26	50% red. cell growth 50% red. floresence	Caux, Menard, and Kent 1996	Supplemental (NOAEC and raw data unavailable)
Chlorophyceae *Kirchneria subcapitata* *= Selenastrum capricornutum* (24 hours; nominal)	Unk.	34 42 53	50% red. 14-carbon uptake; media: Taub & Dollar (TD); algal assay & TD, respect.	45020015 Larsen *et al*. 1986	Supplemental (raw data unavailable)
Cyanophyceae *Anabaena cylindrica* (?? hours; nominal)	97	37	50% red. in photosynthesis	Stratton & Corke 1981	Supplemental (no raw data)
Chlorophyceae *Scenedesmus obliquus* (24 hour; nominal)	Unk.	38 49 57	50% red. 14-carbon uptake; media: Taub & Dollar (TD)	45020015 Larsen *et al*. 1986	Supplemental (raw data unavailable)
Chlorophyceae *Kirchneria subcapitata* *=Selenastrum capricornutum* (120 hours; measured)	97.1	49 NOAEC 16 Slope 4.002	50% red. cell growth	43074802 Hoberg 1993	Core
Cyanophyceae *Anabaena inaequalis* (?? hours; nominal)	97	50	50% red. in photosynthesis	Stratton & Corke 1981	Supplemental (no raw data)
Chlorophyceae *Kirchneria subcapitata* *= Selenastrum capricornutum* (120 hours; nominal)	97.4	53 NOAEC <32 LOAEC 32 Slope 4.127	50% red. growth 17% red. growth	41065204 Parrish 1978	Supplemental (NOAEC, method & raw data unavailable)

Nontarget Freshwater Plant Toxicity (Tier II)

Surrogate Species/ Duration/Measured/nominal	% ai	Conc. (ppb) Probit Slope	% Response	MRID No. Author/Year	Study Classification
Bacillariophyceae Navicula pelliculosa (120 hours; nominal)	97.1	60 NOAEC <10 LOAEC 10 Slope 2.31	50% red. growth	41065203a Hughes 1986	Core (EC50 extrapolated; and NOAEC was not determined)
Chlorophyceae *Ankistrodesmus* sp. (24 hours; nominal)	Unk.	61 72 219	50% red. 14-carbon uptake; media: Taub & Dollar (TD), TD & algal assay, respect.	45020015 Larsen *et al*. 1986	Supplemental (raw data unavailable)
Ulothrix subconstricta Tentative species identification (24 hours; nominal)	Unk.	88	50% red. 14-carbon uptake; medium: Taub & Dollar (TD)	45020015 Larsen *et al*. 1986	Supplemental (raw data unavailable)
Cyanophyceae *Anabaena variabilis* (?? hours; Nominal)	97	100	50% red. in photosnythesis	Stratton & Corke 1981	Supplemental (no raw data)
Stigeoclonium tenue Tentative species Identification (24 hours; nominal)	Unk.	127 224	50% red. 14-carbon uptake; media: Taub & Dollar (TD)	45020015 Larsen *et al*. 1986	Supplemental (raw data unavailable)
Chlorophyceae *Kirchneria subcapitata* =*Selenastrum capricornutum* (96 hours; measured)	97	130 NOAEC 76 Slope 6.628	50% red. cell growth	42060701 Hoberg 1991	Supplemental (higher light intensity than recommended)
Cyanophyceae *Anabaena cylindrica* (24 hour; nominal)	Unk.	178 182 253	50% red. 14-carbon uptake; media: Taub & Dollar (TD), algal assay, & TD, respect.	45020015 Larsen *et al*. 1986	Supplemental (raw data unavailable)
Cyanophyceae *Anabaena flos-aquae* (120 hours; nominal)	97	230 NOAEC <100 LOAEC 100 Slope 1.95	50% red. growth 22% red. growth	41065203a Hughes 1986	Core (NOAEC was not determined)
Chlorophyceae *Chlorella pyrenoidosa* (120 hours; nominal)	97.4	282 NOAEC 130 Slope 4.216	50% red. growth 7% red. growth	41065204 Parrish 1978	Supplemental (NOAEC, method & raw data unavailable)
Chlorophyceae *Chlorella vulgaris* (24 hours; nominal)	Unk.	293 305 325	50% red. 14-carbon uptake; media: Algal assay, Taub & Dollar (TD), & TD, respect.	45020015 Larsen *et al*. 1986	Supplemental (raw data unavailable)

Longer Term, Nontarget Freshwater Plant Toxicity

Surrogate Species/ Duration/ Measured/nominal	% ai	Conc. (ppb) Probit Slope	% Response	MRID No. Author/Year	Study Classification
Vascular Plants:					
Broad Waterweed *Elodea canadensis* (20 days; measured)	????	NOAEC 2 LOAEC 10	200% incr. dark respiration 33% incr. net photosynthesis	45227714 Hofmann and Winkler 1990	Supplemental (raw data unavailable)

Longer Term, Nontarget Freshwater Plant Toxicity

Surrogate Species/ Duration/ Measured/nominal	% ai	Conc. (ppb) Probit Slope	% Response	MRID No. Author/Year	Study Classification
Pondweed *Potamogeton perfoliatus* (4 weeks; initial conc. nominal, terminal conc. measured)	???	30 Week 3: LOAEC 5 NOAEC < 5 4 Weeks: LOAEC 50 NOAEC 5	50% red. O_2 product. sign. red. O_2 product. sign. red. O_2 product.	Kemp *et al*. 1985	Supplemental (raw data unavailable)
Duckweed *Lemna gibba* (14 days; measured)	97.1	37 LOAEC 3.4 NOAEC < 3.4 Slope 1.716	50% red. growth 19% red. growth (frond production)	43074804 Hoberg 1993	Supplemental (NOAEC was not determined)
Duckweed - *Lemna gibba* (14 days; measured)	97.4	43 NOAEC 10 Slope 1.995	50% red. growth (frond production)	43074803 Hoberg 1993	Core
Broad Waterweed *Elodea canadensis* (3 weeks; nominal)	???	80	50% red. shoot length	45087410 Forney and Davis 1981	Supplemental (raw data unavailable)
Eurasian Water-Milfoil *Myriophyllum spicatum* (4 weeks; initial conc. nominal, terminal conc. measured)	????	91 NOAEC 5 LOAEC 50	50% red, O_2 product. Sign. red. O_2 product.	Kemp *et al*. 1985	Supplemental (raw data unavailable)

Non-Vascular Plants:

36 freshwater algal strains (2 weeks; nominal)	99.0	10 1,000	growth <than control strong growth red.	Butler *et al*. 1975	Supplemental (raw data unavailable)
Chlorophyceae *Chlorella vulgaris* (11 days; nominal)	99.9	25	50% red. cell growth	45227703 Burrell *et al. 1985*	Supplemental (raw data unavailable)
Cyanophyceae *Anabaena inaequalis* (12-14 days[1]; nominal)	>95	30 100 300	50% red. cell count 50% red. growth rate 50% red. photosynthesis	45087401 Stratton 1984	Supplemental (NOAEC and raw data unavailable)
Chlorophyceae *Ankistrodesmus braunii* (11 days; nominal)	99.9	60	50% red. cell growth	45227703 Burrell *et al*. 1985	Supplemental (raw data unavailable)
Chlorophyceae *Scenedesmus quadricauda* (12-14 days[1]; nominal)	> 95	100 200 300	50% red. cell count 50% red. growth rate 50% red. photosynthesis	45087401 Stratton 1984	Supplemental (NOAEC and raw data unavailable)
Chlorophyceae *Chlorella pyrenoidosa* (12-14 days[1]; nominal)	> 95	300 1,000 500	50% red. cell count 50% red. growth rate 50% red. photosynthesis	Stratton 1984	Supplemental (NOAEC and raw data unavailable)
Cyanophyceae *Anabaena cylindrica* (12-14 days; nominal)	> 95	1,200 3,600 500	50% red. cell count 50% red. growth rate 50% red. photosynthesis	Stratton 1984	Supplemental (NOAEC and raw data unavailable)

Longer Term, Nontarget Freshwater Plant Toxicity

Surrogate Species/ Duration/ Measured/nominal	% ai	Conc. (ppb) Probit Slope	% Response	MRID No. Author/Year	Study Classification
Cyanophyceae *Anabaena variabilis* (12-14 days; nominal)	> 95	4,000 5,000 100	50% red. cell count 50% red. growth rate 50% red. photosynthesis	Stratton 1984	Supplemental (NOAEC and raw data unavailable)

Nontarget Marine/Estuarine Plant Toxicity (Tier II)

Surrogate Species/ Duration/Measured/nominal	% ai	Conc. (ppb) Probit Slope	% Response	MRID No. Author/Year	Study Classification
Vascular Plants:					
Fontinalis sp. (24 hours; measured)	????	NOAEC 2 LOAEC 10	red. net O_2 production		Supplemental (raw data unavailable)
Pondweed (Estuarine) *Potamogeton perfoliatus* (2 hours; nominal)	????	77	50% red. O_2 evolution	45227718 Jones and Winchell 1984	Supplemental (Insufficient duration; raw data unavailable)
Pondweed *Potamogeton perfoliatus* (2 hours; nominal)	???	80 650	50% red. O_2 product. 87% red. O_2 product..	45227718 Jones *et al*. 1986	Supplemental (Insufficient duration; raw data unavailable)
Zannichellia palustris (2 hours; nominal)	????	91	50% red. O_2 evolution	45227719 Jones and Winchell 1984	Supplemental (Insufficient duration; raw data unavailable)
Pondweed (Estuarine) *Potamogeton perfoliatus* (2 hours; nominal)	Unk.	100	52 to 69% red. in photosynthesis	45087404 Jones & Estes 1984	Supplemental (raw data unavailable)
Widgeon-Grass (Estuarine) Ruppia maritima (2 hours; nominal	?????	102	50% red. O_2 evolution	45227719 Jones and Winchell 1984	Supplemental (Insufficient duration; raw data unavailable)
Non-Vascular Plants:					
Blue-green - Cyanophyceae *Oscillatoria lutea* (1week; nominal)	76 80 W	1 1,000	93% red. chlorophyll production 100% red. chlorophyll prod.	00023544 Torres and O'Flaherty 1976	Supplemental (raw data unavailable)
Green Algae - Chlorophyceae *Stigeoclonium tenue* (1 week; nominal)	76 80 W	1 1,000	67% red. chlorophyll production 90% red. chlorophyll production	00023544 Torres and O'Flaherty 1976	Supplemental (raw data unavailable)
Green Algae - Chlorophyceae *Chlorella vulgaris* (1 week; nominal)	76 80 W	1 1,000	50% red. chlorophyll production 80-87% red. chlorophyll prod.	00023544 Torres and O'Flaherty 1976	Supplemental (raw data unavailable)
Xanthophyceae *Tribonema* sp. (1 week; nominal)	76 80 W	1 1,000	42% red. chlorophyll production 75% red. chlorophyll production	00023544 Torres and O'Flaherty 1976	Supplemental (raw data unavailable)

Nontarget Marine/Estuarine Plant Toxicity (Tier II)

Surrogate Species/ Duration/Measured/nominal	% ai	Conc. (ppb) Probit Slope	% Response	MRID No. Author/Year	Study Classification
Xanthophyceae *Vaucheria geminata* (1 week; nominal)	76 80 W	1 1,000	41% red. chlorophyll production 100% red. chlorophyll prod.	00023544 Torres and O'Flaherty 1976	Supplemental (raw data unavailable)
Chrysophyceae *Isochrysis galbana* (120 hours; nominal)	97.4	22 NOAEC < 13 LOAEC 13 Slope 3.065	50% red. growth 30% red. growth	41065204 Parrish 1978	Supplemental (NOAEC, method & raw data unavailable)
Marine Diatom *Skeletonema costatum* (120 hours; nominal)	97.4	24 NOAEC < 13 LOAEC 13 Slope 3.343	50% red. growth 14% red. growth	41065204 Parrish 1978	Supplemental (NOAEC, method & raw data unavailable)
Marine Diatom Skeletonema costatum (120 hours; measured)	97.1	53 NOAEC 14 Slope 2.798	50% red. cell growth	43074801 Hoberg 1993	Core
Marine Green - Chlorophyceae *Chlamydomonas* sp. (72 hours; nominal); Salinity 30 g/L	99.7	60	50% red. O_2 production	40228401 Mayer 1986	Supplemental (72 hrs & endpoint)
Marine Yellow - Chrysophyceae *Monochrysis lutheri* (72 hours; nominal); Salinity 30 g/L	99.7	77	50% red. O_2 production	40228401 Mayer 1986	Supplemental (72 hrs & endpoint)
Marine Red - Rhodophyceae *Porphyridium cruentum* (72 hours; nominal); Salinity 30 g/L	99.7	79	50% red. in O_2 production	40228401 Mayer 1986	Supplemental (72 hrs & endpoint)
Marine Green - Chlorophyceae *Neochloris* sp. (72 hours; nominal); Salinity 30 g/L	99.7	82	50% red. in O_2 production	40228401 Mayer 1986	Supplemental (72 hrs & endpoint)
Marine Bacillariophyceae Cyclotella nana (72 hours; nominal); Salinity 30 g/L	99.7	84	50% red. in O_2 production	40228401 Mayer 1986	Supplemental (72 hrs & endpoint)
Marine Bacillariophyceae *Achnanthes brevipes* (72 hours; nominal); Salinity 30 g/L	99.7	93	50% red. in O_2 production	40228401 Mayer 1986	Supplemental (72 hrs & endpoint)
Marine Yellow - Chrysophyceae *Isochrysis galbana* (240 hours; nominal); Salinity 30 g/L	99.7	100	50% red. cell growth	40228401 Mayer 1986	Supplemental (NOAEC unavailable)

Nontarget Marine/Estuarine Plant Toxicity (Tier II)

Surrogate Species/ Duration/Measured/nominal	% ai	Conc. (ppb) Probit Slope	% Response	MRID No. Author/Year	Study Classification
Marine Green - Chlorophyceae *Chlorococcum* sp. (240 hours; nominal); Salinity 30 g/L	99.7	100	50% red. cell growth	40228401 Mayer 1986	Supplemental (NOAEC unavailable)
Marine Green - Chlorophyceae *Platymonas* sp. (72 hours; nominal); Salinity 30 g/L	99.7	100	50% red. O_2 production	40228401 Mayer 1986	Supplemental (72 hrs & endpoint)
Marine Bacillariophyceae *Thalassiosira fluviatilis* (72 hours; nominal); Salinity 30 g/L	99.7	110	50% red. O_2 production	40228401 Mayer 1986	Supplemental (72 hrs & endpoint)
Marine Bacillariophyceae *Stauroneis amphoroides* (72 hours; nominal); Salinity 30 g/L	99.7	110	50% red. O_2 production	40228401 Mayer 1986	Supplemental (72 hrs & endpoint)
Marine Algae *Microcystis aeruginosa* (120 hours - nominal)	97.4	129 NOAEC 65 Slope 3.162	50% red. growth 7% red. growth	41065204 Parrish 1978	Supplemental (NOAEC, method & raw data unavailable)
Marine Green - Chlorophyceae *Chlorella* sp. (72 hours; nominal); Salinity 30 g/L	99.7	140	50% red. O_2 production	40228401 Mayer 1986	Supplemental (NOAEC unavailable
Blue-green - Cyanophyceae *Anabaena cylindrica* (24 hour; nominal)	Unk.	178 182 253	50% red. 14-carbon uptake; media: Taub & Dollar (TD), algal assay, & TD, respect.	45020015 Larsen *et al*. 1986	Supplemental (raw data unavailable)
Marine green - Chlorophyceae *Dunaliella tertiolecta* (120 hours; nominal)	97	180 NOAEC < 100 LOAEC 100 Slope 1.95	50% red. growth 34% red. growth	41065203 Hughes 1986	Supplemental (NOAEC unavailable)
Marine Yellow - Chrysophyceae Phaeodactylum tricornutum (240 hours; nominal); Salinity 30 g/L	99.7	200	50% red. cell growth	40228401 Mayer 1986	Supplemental (NOAEC unavailable)
Marine Bacillariophyceae *Nitzschia closterium* (72 hours; nominal); Salinity 30 g/L	99.7	290	50% red. O_2 production	40228401 Mayer 1986	Supplemental (72 hrs & endpoint)
Marine Bacillariophyceae *Amphora exigua* (72 hours; nominal); Salinity 30 g/L	99.7	300	50% red. O_2 production	40228401 Mayer 1986	Supplemental (72 hrs & endpoint)

Nontarget Marine/Estuarine Plant Toxicity (Tier II)

Surrogate Species/ Duration/Measured/nominal	% ai	Conc. (ppb) Probit Slope	% Response	MRID No. Author/Year	Study Classification
Marine Green - Chlorophyceae *Dunaliella tertiolecta* (240 hours; nominal); Salinity 30 g/L	99.7	300	50% red. cell growth	40228401 Mayer 1986	Supplemental (NOAEC unavailable)
Marine Red - Rhodophyceae *Porphyridium cruentum* (120 hours)	97.4	308 NOAEC <130 LOAEC 130 Slope 2.449	50% red. growth 16% red. growth	41065204 Parrish 1978	Supplemental (NOAEC, method & raw data unavailable)
Marine Bacillariophyceae *Nitzschia* (Ind. 684) (72 hours; nominal); Salinity 30 g/L	99.7	430	50% red. O_2 production	40228401 Mayer 1986	Supplemental (72 hrs & endpoint)
Marine Green -Chlorophyceae *Kirchneria subcapitata* (120 hours; nominal)	97.4	431 NOAEC 200 Slope 4.217	5% red. in growth 4% red. in growth	41065204 Parrish 1978	Supplemental (NOAEC, method & raw data unavailable)
Marine Bacillariophyceae *Navicula inserta* (72 hours; nominal); Salinity 30 g/L	99.7	460	50% red. in O_2 production	40228401 Mayer 1986	Supplemental (72 hrs & endpoint)

Formulation Nontarget Marine/Estuarine Algal Toxicity (Tier II)

Species/ Duration/Measured/nominal	% ai	Conc. (ppb) Probit slope	% Response	MRID No. Author/Year	Study Classification
Mar. Yellow - Chrysophyceae *Isochrysis galbana* (nominal); Salinity 30 g/L	76 80 WP	100 (240 hrs) 200 (2 hrs)	50% red. cell growth 50% red. O_2 production	40228401 Mayer 1986	Supplemental (NOAEC unavailable)
Mar. Yellow Chlorophyceae *Chlorococcum* sp. (nominal); Salinity 30 g/L	76 80 WP	100 (240 hrs) 400 (2 hrs)	50% red. cell growth 50% red. O_2 production	40228401 Mayer 1986	Supplemental (NOAEC unavailable)
Mar. Yellow - Chrysophyceae Phaeodactylum tricornutum (nominal); Salinity 30 g/L	76 80 WP	200 (240 hrs) 200 (2 hrs)	50% red. cell growth 50% red. O_2 production	40228401 Mayer 1986	Supplemental (NOAEC unavailable)
Mar. Green - Chlorophyceae *Dunaliella tertiolecta* (nominal); Salinity 30 g/L	76 80 WP	400 (240 hrs) 600 (2 hrs)	50% red. cell growth 50% red. O_2 production	40228401 Mayer 1986	Supplemental (NOAEC unavailable)

Longer-term Nontarget Marine/Estuarine Plant Toxicity

Surrogate Species/ Duration/Measured/nominal	% ai	Conc. (ppb) Probit Slope	% Response	MRID No. Author/Year	Study Classification
Vascular Plants:					

Longer-term Nontarget Marine/Estuarine Plant Toxicity

Surrogate Species/ Duration/Measured/nominal	% ai	Conc. (ppb) Probit Slope	% Response	MRID No. Author/Year	Study Classification
Sago Pondweed (Estuarine) *Potamogeton pectinatus* (28 days; measured/nominal)	???	Salinity 12 ppt: NOAEC 7.5 LOAEC 14.3 Salinity 1 & 6 ppt: NOAEC 14.3 LOAEC 30	 sign. red. dry weight sign. red. dry weight	45088231 Chesapeake Bay Program 1998	Supplemental (raw data unavailable)
Estuarine rush *Juncus roemerianus* (5 weeks - 1 year; measured	97.1	LOAEC 30 NOAEC 30 NOAEC < 30 250 ppb 3, 800 ppb	sign. red. chlorophyll a in 5 weeks (1 year) partial recovery (1 yr) practically no survival	45087405 Lytle & Lytle 1998	Supplemental (raw data unavailable)
Pondweed *Potamogeton perfoliatus* (4 weeks; initial conc. nominal, terminal conc. measured)	???	30 Week 3: LOAEC 5 NOAEC < 5 4 weeks: LOAEC 50 NOAEC 5	50% red. O_2 product. sign. red. O_2 product. sign. red. O_2 product.	45227720 Kemp *et al*. 1985	Supplemental (raw data unavailable)
Pondweed (Estuarine) *Potamogeton perfoliatus* (3 weeks; nominal)	???	53	50% red. ????	45087410 Forney and Davis 1981	Supplemental (raw data unavailable)
Eelgrass (Estuarine) *Zostera marina* (10 days; measured)	Unk.	est. 69 50 80	50% red. leaf growth 25% red. leaf growth 62% red. leaf growth	45227729 Schwarzschild *et al*. 1994	Supplemental (raw data unavailable)
Estuarine Eelgrass *Zostera marina* (21 days; nominal)	???	100 NOAEC 10	21-day LC50 red. production	45227705 Delistraty and Hershner 1984	Supplemental (raw data unavailable)
Wild Celery (Estuarine) *Vallisneria americana* (6 weeks; nominal)	???	163	50% red. shoot length no difference at 0, 3, or 6 parts/thousand	45087410 Forney and Davis 1981	Supplemental (raw data unavailable)
Seagrass (Estuarine) *Halodule wrightii* (22 - 23 days; measured)	Atrazine 4L	30,000	46-58% red. total above-ground biomass	45205101 Mitchell 1987	Supplemental (raw data unavailable)

Non-Vascular Plants:

Marine Brown macroalgae *Laminaria hyperborea* (18 days; nominal)	???	NOAEC < 10 LOAEC 10 50 & 100	sign. red. growth rate delayed sporophyte formation	???? Hopkin &Kain 1978	Supplemental (raw data unavailable)
Marine Yellow - Chrysophyceae *Isochrysis galbana* (240 hours; nominal); Salinity 30 g/L	99.7	100	50% red. cell growth	40228401 Mayer 1986	Supplemental (NOAEC unavailable)

Longer-term Nontarget Marine/Estuarine Plant Toxicity

Surrogate Species/ Duration/Measured/nominal	% ai	Conc. (ppb) Probit Slope	% Response	MRID No. Author/Year	Study Classification
Marine Green - Chlorophyceae *Chlorococcum* sp. (240 hours; nominal); Salinity 30 g/L	99.7	100	50% red. cell growth	40228401 Mayer 1986	Supplemental (NOAEC unavailable)
Marine Yellow - Chrysophyceae Phaeodactylum tricornutum (240 hours; nominal); Salinity 30 g/L	99.7	200	50% red. cell growth	40228401 Mayer 1986	Supplemental (NOAEC unavailable)
Marine Green - Chlorophyceae *Dunaliella tertiolecta* (240 hours; nominal); Salinity 30 g/L	99.7	300	50% red. cell growth	40228401 Mayer 1986	Supplemental (NOAEC unavailable)

The Tier II results indicate that the marine algae *Isochrysis galbana* is the most sensitive nonvascular aquatic plant (EC_{50} 22 ppb) and the most sensitive vascular aquatic plant is wild celery (4 ppb). Comparison of atrazine toxicity levels for three different endpoints suggest that the endpoints in decreasing order of sensitivity are cell count, growth rate and oxygen production (Stratton 1984). Walsh (1983) exposed *Skeletonema costatum* to atrazine and concluded that atrazine is only slightly algicidal at relatively high concentrations (i.e., 500 & 1,000 ppb). Caux *et al*. (1996) compared the cell count IC_{50} and fluorescence LC_{50} and concluded that atrazine is algicidal at concentrations which effect cell counts. Abou-Waly *et al*. (1991) measured growth rates on days 3, 5, and 7 for two algal species. The pattern of atrazine effects on growth rates differ sharply between the two species. Atrazine had a strong early effect on *Anabaena flos-aquae* followed by rapid recovery in clean water (i.e., EC_{50} values for days 3, 5, and 7 are 58, 469, and 766 ppb, respectively). The EC_{50} values for *Selenastrum capricornutum* continued to decline from Day 3 through 7 (i.e., 283, 218, and 214 ppb, respectively. Based on theses results, it appears that the timing of peak effects for atrazine may differ depending on the test species. The guideline requirement (123-2) is fulfilled for only three out of five species (MRID 43074801, 43074802, 43074803). However, sufficient data exists on numerous other algal species to provide a broad range of toxicity effects. No additional algal studies are required.

Degradates: The major atrazine degradate is hydroxyatrazine which forms a large percent of the recoverable pesticide in aquatic compartments of the environment. Therefore, special tests are required for algal and vascular plant species (123-2) to address concerns for the toxicity of atrazine degradates to aquatic plants.

Degradate Deethylatrazine Nontarget Aquatic Plant Toxicity (Tier II)

Species/ Duration/Measured/nominal	% ai	Conc. (ppb) Probit slope	% Response	MRID No. Author/Year	Study Classification
Fresh. Blue-Green - Cyanophyceae	> 95	1,000	50% red. cell count	Stratton 1984	Supplemental
Anabaena inaequalis		4,000	50% red. growth rate		(NOAEC and raw data
(12-14 days[1]; nominal)		2,500	50% red. photosynthesis		unavailable)
Freshwater Green - Chlorophyceae	> 95	1,200	50% red. cell count	Stratton 1984	Supplemental
Scenedesmus quadricauda		2,000	50% red. Growth rate		(NOAEC and raw data
(12-14 days; nominal)		1,800	50% red. photosynthesis		unavailable)
Freshwater Green - Chlorophyceae	> 95	3,200	50% red. cell count	Stratton 1984	Supplemental
Chlorella pyrenoidosa		7,200	50% red. growth rate		(NOAEC and raw data
(12-14 days[1]; nominal)		1,800	50% red. photosynthesis		unavailable)
Fresh. Blue-Green - Cyanophyceae	> 95	3,500	50% red. cell count		Supplemental
Anabaena variabilis		7,500	50% red. growth rate	Stratton 1984	(NOAEC and raw data
(12-14 days; nominal)		700	50 % red. photosynthesis		unavailable)
Fresh. Blue-Green - Cyanophyceae	> 95	8,500	50% red. cell count		Supplemental
Anabaena cylindrica		5.500	50% red. growth rate	Stratton 1984	(NOAEC and raw data
(12-14 days; nominal)		4,800	50% red. photosynthesis		unavailable)

Degradate Deisopropylatrazine Nontarget Aquatic Plant Toxicity (Tier II)

Species/ Duration/Measured/nominal	% ai	Conc. (ppb) Probit slope	% Response	MRID No. Author/Year	Study Classification
Fresh. Blue-Green - Cyanophyceae	> 95	2,500	50% red. cell count		Supplemental
Anabaena inaequalis		7,000	50% red. growth rate	Stratton 1984	(NOAEC and raw data
(12-14 days[1]; nominal)		9,000	50% red. photosynthesis		unavailable)
Freshwater Green - Chlorophyceae	> 95	6,900	50% red. cell count		Supplemental
Scenedesmus quadricauda		6.500	50% red. Growth rate	Stratton 1984	(NOAEC and raw data
(12-14 days; nominal)		4,000	50% red. photosynthesis		unavailable)
Freshwater Green - Chlorophyceae	> 95	> 10,000	50% red. cell count		Supplemental
Chlorella pyrenoidosa		> 10,000	50% red. growth rate	Stratton 1984	(NOAEC and raw data
(12-14 days[1]; nominal)		3,600	50% red. photosynthesis		unavailable)
Fresh. Blue-Green - Cyanophyceae	> 95	5,500	50% red. cell count		Supplemental
Anabaena variabilis		9,200	50% red. growth rate	Stratton 1984	(NOAEC and raw data
(12-14 days; nominal)		4,700	50 % red. photosynthesis		unavailable)
Fresh. Blue-Green - Cyanophyceae	> 95	> 10,000	50% red. cell count		Supplemental
Anabaena cylindrica		> 10,000	50% red. growth rate	Stratton 1984	(NOAEC and raw data
(12-14 days; nominal)		9,300	50% red. photosynthesis		unavailable)

Degradate Diamino-Atrazine Nontarget Aquatic Plant Toxicity (Tier II)

Species/ Duration/Measured/nominal	% ai	Conc. (ppb) Probit slope	% Response	MRID No. Author/Year	Study Classification
Fresh. Blue-Green - Cyanophyceae	> 95	7,000	50% red. cell count		Supplemental
Anabaena inaequalis		>10,000	50% red. growth rate	Stratton 1984	(NOAEC and raw data
(12-14 days[1]; nominal)		>100,000	50% red. photosynthesis		unavailable)
Freshwater Green - Chlorophyceae	> 95	4,600	50% red. cell count		Supplemental
Scenedesmus quadricauda		10,000	50% red. Growth rate	Stratton 1984	(NOAEC and raw data
(12-14 days; nominal)		>100,000	50% red. photosynthesis		unavailable)

Degradate Diamino-Atrazine Nontarget Aquatic Plant Toxicity (Tier II)

Species/ Duration/Measured/nominal	% ai	Conc. (ppb) Probit slope	% Response	MRID No. Author/Year	Study Classification
Freshwater Green - Chlorophyceae	> 95	>10,000	50% red. cell count		Supplemental
Chlorella pyrenoidosa		>10,000	50% red. growth rate	Stratton 1984	(NOAEC and raw data
(12-14 days[1]; nominal)		>100,000	50% red. photosynthesis		unavailable)
Fresh. Blue-Green - Cyanophyceae	> 95	>10,000	50% red. cell count		Supplemental
Anabaena variabilis		>10,000	50% red. growth rate	Stratton 1984	(NOAEC and raw data
(12-14 days; nominal)		100,000	50 % red. photosynthesis		unavailable)
Fresh. Blue-Green - Cyanophyceae	> 95	>10,000	50% red. cell count		Supplemental
Anabaena cylindrica		>10,000	50% red. growth rate	Stratton 1984	(NOAEC and raw data
(12-14 days; nominal)		>100,000	50% red. photosynthesis		unavailable)

Degradate Hydroxyatrazine Nontarget Aquatic Plant Toxicity (Tier II)

Species/ Duration/Measured/nominal	% ai	Conc. (ppb) Probit slope	% Response	MRID No. Author/Year	Study Classification
Fresh. Blue-Green - Cyanophyceae	> 95	>10,000	50% red. cell count		Supplemental
Anabaena inaequalis		>10,000	50% red. growth rate	Stratton 1984	(NOAEC and raw data
(12-14 days[1]; nominal)		>100,000	50% red. photosynthesis		unavailable)
Freshwater Green - Chlorophyceae	> 95	>10,000	50% red. cell count		Supplemental
Scenedesmus quadricauda		>10,000	50% red. Growth rate	Stratton 1984	(NOAEC and raw data
(12-14 days; nominal)		>100,000	50% red. photosynthesis		unavailable)
Freshwater Green - Chlorophyceae	> 95	>10,000	50% red. cell count		Supplemental
Chlorella pyrenoidosa		>10,000	50% red. growth rate	Stratton 1984	(NOAEC and raw data
(12-14 days[1]; nominal)		>100,000	50% red. photosynthesis		unavailable)
Fresh. Blue-Green - Cyanophyceae	> 95	>10,000	50% red. cell count		Supplemental
Anabaena variabilis		>10,000	50% red. growth rate	Stratton 1984	(NOAEC and raw data
(12-14 days; nominal)		>100,000	50 % red. photosynthesis		unavailable)
Fresh. Blue-Green - Cyanophyceae	> 95	>10,000	50% red. cell count		Supplemental
Anabaena cylindrica		>10,000	50% red. growth rate	Stratton 1984	(NOAEC and raw data
(12-14 days; nominal)		>100,000	50% red. photosynthesis		unavailable)

The Tier II results for atrazine degradates indicate that deethylatrazine is more toxic than the other four degradates and the most sensitive algae of the five species usually is the blue-green alga *Anabaena inaequalis* with EC_{50} values ranging from 100 to > 100,000 ppb. Atrazine is more toxic to these algal than any degradate. The order of descending toxicity for these algal species are atrazine > deethylatrazine > deisopropylatrazine > diamino-atrazine > hydroxy-atrazine. The data are useful, but the test species are not the species specified for pesticide registration. The requirement (123-2) has not been fulfilled.

e. Multi-species Tests (Microcosms, Field Studies)

i. Simulated Aquatic Field Studies (Microcosms)

a. Freshwater Microcosm Tests

Application rate (lb ai/A) Nominal/Measured Conc.	Concentration affecting endpoint (time to effect) o percent difference from controls	Narrative of Study Trends	MRID No. Author/Year
Freshwater microcosm: Measured close to nominal throughout the testing period: concentrations of 0.5, 5, 50, 100, 500, and 5000 ppb	0.5 and 5 ppb o no reduction in net oxygen loss 50 ppb o 25-30% reduction in net oxygen loss 100 ppb o 40-50% reduction in net oxygen loss 500 ppb o 90% reduction in net oxygen loss 5,000 ppb o 100% reduction to negative net oxygen production	*Spirogyra, Oedogonium, Microcystis, Apthanothece, and Scenedesmus* sp. in mixed culture. Microcosms inoculated with algae demonstrated effects at concentrations ≥50 ppb. Physical appearance of the microcosms was altered at 5,000 ppb. Observations and reculture demonstrated that the effects were algistatic.	45087407 Brockway *et al*., 1984
Freshwater Microcosm: (Duration 7 weeks exposure) Mean measured concentrations of 5.08 ± 0.03 μg/L; range: 4.2 - 6.0 μg/L	NOEC: 5 ppb o slight non-sign. shifts in water parameters: o DO decreased from means of 9.4 - 9.9 mg/L (controls) differing weekly by 0.2 - 0.6 mg/L o pH decreased from means of 8.4 - 9.0 (controls) differing weekly by 0.0 - 0.4 units o conductivity increased from 159.3 - 189.3 μS/cm (controls) differing by 0.2 - 10.0 μS/cm o alkalinity increased from means of 1.4 - 2.2 mg/L (controls) differing by 0.0 - 0.3 mg/L o no significant adverse effects on phyto- & zooplankton, or 15 macro-invertebrate species o Cyclopoida sign. increased in week 3	Laboratory microcosms (4 replicates) were tested with 0 and 5 μg/L atrazine for 7 weeks. The plankton and macro-invertebrates were introduced together with 2-cm layer of natural sediments into glass aquaria with a 50 cm water column with a 14-hour photoperiod. Water was circulated through the microcosms at a flow rate of 3.5 L/min. during an acclimation period for biota of 3 months. This test was part of a study of pesticide interaction between atrazine and chlorpyrifos to determine the adequacy of chronic safety factors.	45087417 van den Brink *et al.* 1995 Supplemntal (raw data unavailable)
Freshwater Microcosm: Mean measured concentrations of 3.2, 10, 32, 110, and 337 ppb	NOEC: 10 ppb; LOEC: 32 ppb o dissolved oxygen, magnesium, and calcium; NOEC: 110 ppb; LOEC: 337 ppb o potassium, chlorophyll-a, protein, and species equilibrium number	Laboratory microcosms were inoculated with foam blocks taken from a pond. The effect to protozoans from atrazine exposure was examined by measuring structure (species number, biomass), and function (colonization rate, oxygen production, chlorophyll concentration) of the community as well as ion concentrations of the biomass after 21 days.	45087416 Pratt *et al*. 1988 Supplemental (raw data unavailable)
Freshwater Microcosm: (6 weeks) Meas. peak 20 ppb on day 1, mean measured concentration of approximately 10 ppb	10 ppb (6 weeks) o sign. (0.05) reduced dissolved oxygen (DO), but was recovering by test termination	Laboratory microcosms were treated with a stock solution of atrazine and soil to which atrazine was bound. At the end of the study, no significant effects on plant biomass or daphnid/midge survival were noted, but DO was affected.	45205102 Huckins *et al*. 1986 Supplemental (raw data unavailable)

Application rate (lb ai/A) Nominal/Measured Conc.	Concentration affecting endpoint (time to effect) o percent difference from controls	Narrative of Study Trends	MRID No. Author/Year
Freshwater microcosm: (30 days): Macrophytes, algae, zooplankton and benthic invertebrates; Nominal conc. of 10, 100 and 1,000 ppb as a soil slurry	10 ppb (Day 2) o 23% red. in gross primary productivity (GPP); recovery by Day 7 and similar to controls at Day 30 100 ppb (Day 2) o 32% red. in GPP; recovery by Day 7 and similar to controls at Day 30 1,000 ppb (Day 2) o 91% red. in GPP; no recovery, 70% red. throughout test 1,000 ppb (Day 30) o 48% red. (sign. P≤0.05 level) macrophyte biomass o 36% red. (sign., P≤0.05) *Selenastrum* dry weight 1,000 ppb (30-day aged microcosm water) o 76% red. (sign. P≤0.05) *Selenastrum* dry weight 1,000 ppb (Day 30) o reduced O_2, community respiration, pH o 20% increase in conductivity o 120% increase in alkalinity o no effect on soil microbial activity	4-L microcosms were established in the laboratory and treated with a soil slurry of atrazine. The endpoints examined over the 30-day experiment included effects to zoo- and phytoplankton as well as macrophytes (i.e., *Lemna* sp., *Ceratophyllum* sp., and *Elodea* sp.). Static acute and chronic assays were conducted with *Daphnia magna* and *Chironomus riparius* using treated water that had come from the microcosm after 30 days or from a vessel that contained the treated water for 30 days (i.e., aged treated water). The author concluded that microcosm itself ameliorated the phytotoxic effect at 1,000 ppb. No effect on invertebrates up to 1,000 ppb and effects to phytoplankton at 10 and 100 ppb were not observed by test termination (30 days). Conductivity, pH, and alkalinity were also affected at 1,000 ppb.	45087413 Johnson, 1986 Supplemental (raw data unavailable)
Freshwater Microcosm: Emergent vascular plants; Nominal water conc. of 10, 50, 100, 500, and 1,500 ppb; measured water conc. in the 50 and 500 ppb treatments of 1.3 and 1.6 ppb, respectively, after 16 weeks	500 ppb (6 weeks) o sign. (0.05 level) red. shoot length of *Scirpus acutus* 1,500 ppb (6 weeks) o sign. red. shoot length of *Scirpus acutus* and *Typha latifolia*	Greenhouse microcosms were made by placing rhizome sections in tubs which were filled with treated water to 1 cm above the soil surface. The plants were allowed to grow for 16 weeks and shoot height of hardstem bulrush and broad-leaved cattail was monitored bi-weekly. Also non-sign. effects of chlorosis and reduced growth noted at 50 and 100 ppb. A second test demonstrated resiliency of both plants at 500 ppb.	45087415 Langan and Hoagland, 1996 Supplemental (raw data unavailable)
Freshwater Microcosm: (14 days) Measured atrazine concentrations approximately 75% of nominal (15 and 153 ppb) for first application and 150% of nominal (385 and 2,167 ppb) for the second application	Sign. (0.1 level) reduction in turbidity and chlorophyll (7 days), and increase in phosphorous (day 14) and nitrogen (days 7 and 14) after the 1st application. Copepod and rotifer densities were also sign. reduced on days 7 and 14. Sign. reductions in productivity, chlorophyll, green algal colonies, rotifers, and *Bosmina* sp. (zooplankton) after 2nd application. Phosphorous, nitrogen, and pH were also sig. affected.	A 3x3 factorial design with three conc. of atrazine (0, 15, and 153 ppb) and three conc. of bifenthrin (0, 0.039, and 0.287 ppb) applied as soil slurry in May, then again one month later but with atrazine conc. of 0, 385, and 2,167 ppb and bifenthrin conc. of 0, 0.125, and 3.15 ppb. Atrazine alone caused dose-responsive reductions in chlorophyll, turbidity, primary production, increases in nitrogen and phosphorous, and reduced levels of chlorophytes, cladocerans, copepod nauplii, and rotifers. General recovery after 14 days for atrazine alone in the first phase, but recovery not complete at sampling termination after second phase (14 days). No synergistic or antagonistic effects were noted.	45020014 Hoagland *et al*., 1993 Supplemental (raw data unavailable)

Application rate (lb ai/A) Nominal/Measured Conc.	Concentration affecting endpoint (time to effect) o percent difference from controls	Narrative of Study Trends	MRID No. Author/Year
Freshwater microcosm: (2 months; measured) Nominal concentrations of 0, 60, 100, 200, 500, 1,000 and 5,000 ppb. Measurements made three times during the two month study.	60 ppb (nominal) o 14-carbon uptake decreased immediately after treatment; recovery began after 10 days; o stimulated production of chlorophyll a; 100 ppb (nominal) o 14-carbon uptake decreased immediately after treatment; recovery began after 10 days; o stimulated production of chlorophyll a; 200 ppb (nominal) o 14-carbon uptake decreased immediately after treatment; slight recovery 2 months after treatment; o stimulated production of chlorophyll a; o inhibited increases in dissolved oxygen during light phase and decreases in DO during dark phase 500 ppb (nominal) o 14-carbon uptake decreased immediately after treatment; no recovery; o minimal inhibition of chlorophyll a production; 1,000 and 5,000 ppb (nominal) o 14-carbon uptake decreased immediately after treatment; recovery began after 10 days. EC50s for Days 0-10, 53-60, & Mean (mean measured conc.) Time period; 14C uptake; DO (light); DO (dark) Days 0-10 : 103 ppb 126 ppb 106 ppb Days 53-60: 159 ppb 154 ppb 164 ppb Days 1-60: 131 ppb 165 ppb 142 ppb	Results of single species assays, microcosm, and pond studies were compared. 14-Carbon fixation was used as the end-point for all three study types. Laboratory results with eight algal species ranged from 37 to 308 ppb for carbon uptake inhibition EC_{50} values. Microcosm EC_{50} values ranged from 103 to 159 ppb. The mean pond EC_{50} was 100 ppb for carbon uptake and 82 ppb for chlorophyll-a inhibition. The authors stated that multiple laboratory studies or a microcosm study represent(s) entire ecosystem functional effects.	45020015 Larsen *et al.*, 1986 and 45087419 Stay *et al.* 1985 Supplemental (raw data unavailable)
Freshwater microcosm: (60 days; measured) Nominal concentrations of 60, 100, 200, 500, 1,000, and 5,000 ppb. Concentrations measured on Days 7, 28, 53, 60.	NOEC < 60 ppb; 60 ppb (1 - 20 days) o sign. (0.05) red. 14-carbon uptake for first 20 days ≥ 100 ppb (2 weeks) o sign. (0.05 level) red. primary productivity; o sign. red. in productivity/ dark respiration ratio; o pH sign. less than control values ≥ 500 ppb (6 weeks) o all endpoints declined immediately after treatment and never recovered during the experiment.	Taub microcosms were 3-L jars inoculated with 10 algal species on Day 0, *Daphnia magna* and 4 other animal species on Day 4. On Day 7, 27 microcosms were treated with atrazine; no other atrazine treatments um from four different aquatic systems. Community metabolism was measured for primary productivity and light and dark respiration. At the high treatment levels (500, 1000 and 5000 ug/L), all process variables declined immediately after atrazine treatment and did not recover during the experiment. At the low treatment levels (60, 100 and 200 ug/L), the magnitude of the responses to atrazine was not constant, but with 3 phases; an autotrophic phase, daphnid bloom and an equilibrium phase.	45087419 Stay *et al.*, 1989 Supplemental (raw data unavailable)

Application rate (lb ai/A) Nominal/Measured Conc.	Concentration affecting endpoint (time to effect) o percent difference from controls	Narrative of Study Trends	MRID No. Author/Year
Freshwater microcosm: (6 weeks; measured) Single dose; Nominal conc. 20, 100, 200, 500, 1,000 and 5,000 ppb. Concentrations were measured on Days 0 and 42. On Day 42, atrazine levels averaged 69 to 80% of the initial concentrations.	NOEC = 20 ppb LOEC = 100 ppb in 3 out of 4 natural plankton communities and 200 ppb for the fourth community. $\geq$ 100 ppb (2 weeks) o sign. (0.05 level) red. primary productivity o sign. red. in productivity/dark respiration ratio o pH sign. less than control values	Leffler microcosms were constructed with inoculum from four different aquatic systems from natural communities and contains organisms representing several trophic levels. The vessels were dosed after 6 weeks of seeding and monitoring for 6 more weeks. The LOEC for 3 of the systems was reported to be 100 ppb, while the LOEC for the fourth was 200 ppb.	45087418 Stay *et al*. 1989 Supplemental (raw data unavailable)

b. Marine/Estuarine Microcosm Tests

Application rate (lb ai/A) Nominal/Measured Conc.	Concentration affecting endpoint (time to effect) o percent difference from controls	Narrative of Study Trends	MRID No. Author/Year
Estuarine microcosm: (; nominal) Wild Celery *Vallisneria americana* 1 treatment Nominal concentrations of 4, 8, 16, 32, and 64 ppb	NOEC < 4 ppb 4 ppb (reproductive season) o sign. 16% reduction in tuber formation o 55% reduction in biomass 8 ppb (reproductive season) o 21% reduction in tuber formation 16 ppb (mid season and reproductive season) o 60% reduction in tuber formation o 27% reduction in tuber weight o sign. reduction in leaf growth, biomass, and female flowers 64 ppb (reproductive season) o 75% reduction in tubers o red. female flowers	Laboratory microcosms were used to grow *Vallisneria americana* through entire seasons (divided into three periods - early-, mid-, and reproductive). The aquaria were dosed one time at the nominal conc. after a 14-day acclimation period. With respect to leaf growth, atrazine caused the plants to be shorter and more fragile. With respect to flowering and rhizome production, effects were generally first noted at the 16 to 32 ppb range. Tuber formation appeared to be the most sensitive endpoint, with production in terms of numbers significantly reduced at the 4 ppb level.	45020001 Cohn 1985 Supplemental (raw data unavailable)
Estuarine lab. microcosm: (7-day exposure; nominal) Nominal concentrations of 22, 220, and 2,200 ppb Estuarine field microcosm: (108-days; nominal) Single exposure; Nominal applications of 0.4, 1.4, 4.5, and 45 lb ai/A	"NOEC" = 10 ppb (based on author's use of a 10-fold safety factor from the I_1 level = 100 ppb) 220 ppb (1 week) o sign. (0.05 level) red. in cell # of *Thalassiosira fluviatilis* o sign. red. in photosynthesis of *T. fluviatilis* and *Nitzschia sigma* 2,200 ppb (1 week) o sign. red. in cell #, photosynthesis., and chlorophyll content for both algae 1.4 lb ai/A (effect up to 5 days) o sign. red. in surface chlorophyll and primary prod. (85-89%) 1.4 lb ai/A (effect up to 8 & 17 days) o sign. reduction in carbon fixation (52-73%) 0.4/4.5 lb ai/A (effect at 16 days, but not 26 days) o sign. reduction in carbon fixation 45 lb ai/A (42 days) o sign. red. in carbon fixation	Laboratory studies were conducted with the salt marsh edaphic diatoms *Thalassiosira fluviatilis* and *Nitzschia sigma*. The I_{50} for both species combined was reported to be 939 ppb. The I_1 was reported to be 100 ppb, and by applying a 10-fold safety factor, the acceptable level (NOEC) was reported to be 10 ppb. Subsequently, studies were conducted in greenhouse microcosms (1.4 lb ai/A) and in two field studies (1.4 lb ai/A or 0.4, 4.5, and 45 lb ai/A) on the beach wherein enclosures were sunk into the sand and exposed to tidal action. Atrazine treatment also appeared to cause a shift to a *Navicula* sp. dominated system. Field results with higher rates of atrazine were as expected, with carbon fixation reduced for up to 16 days at the 2 lower rates and up to 42 days at the highest rate.	45087406 Plumley and Davis, 1980 Supplemental (raw data unavailable)

Application rate (lb ai/A) Nominal/Measured Conc.	Concentration affecting endpoint (time to effect) o percent difference from controls	Narrative of Study Trends	MRID No. Author/Year
Estuarine microcosm: (5 Weeks; measured) 3 weekly applications followed by 2 weeks observation. Mean measured concen. at approximately mid-point of the *Spartina* test were 30, 280, and 3,100 ppb and in the *Juncus* test were 30, 250 and 3,800 ppb.	30, 280, and 3,100 ppb (5 weeks) o sign. (0.05 level) increase in peroxidase activity in *Spartina alterniflora* 30, 250, and 3,800 ppb (5 weeks) o sign. (0.05 level) red. in chlorophyll-a (Chl-a) and Chl-a/Chl-b ratio in *Juncus roemerianus* 250 and 3,800 ppb (5 weeks) o sign. red. in Chl-b in *J. roemerianus* 3,100 ppb (1 week) o sign. red. in growth in *S. alterniflora* 3,800 ppb (5 weeks) o sign. red. in growth in *J. roemerianus* o sign. increase in oxidized lipids in *J. roemerianus* 250 ppb (1 year) o partial recovery in *J. roemerianus* 3,800 ppb (1 year) o practically no survival of *J. roemerianus*.	Two aquatic estuarine plants were exposed to atrazine in greenhouse microcosms. The plants were exposed to atrazine by placing treated sand on the surface of the pots three times (once a week for the first 3 weeks of the study) followed by 2 more weeks for a total of 5 weeks. The water samples were taken after the third application. The pots were also tidally-exposed (i.e., low tide during the day and high tide at night). *S. alterniflora* plants demonstrated a dose-response increase in peroxidase activity. In contrast, *J. roemerianus* plants demonstrated a dose-responsive reduction in chlorophyll and an increase in the amount of oxidized lipids. The authors state that atrazine "should pose no significant adverse effects on *S. alterniflora*. In contrast, if chronic levels of atrazine persist in the range of 250 ug/L or greater, *J. roemerianus* most likely will exhibit die off or decline that may lead to loss of this species within the habitat."	45087405 Lytle and Lytle, 1998 Supplemental (raw data unavailable)
Estuarine microcosm: (???? days, nominal) Nominal concentrations of 0, 50, and 100 ppb	Both *Nannochloris oculata* and *Phaeodactylum tricornutum* were significantly (mostly at the 0.01 level) affected by changes in light, temperature, and atrazine conc.	A 3x3x3 factorial design examined the effect of temperature, light, and atrazine conc. on two species of estuarine algae. *N. oculata* was sig. affected by all variables, and the three two-way and one three-way interactions were also significant. *P. tricornutum* was affected by the main variables and the only sig. interaction was light by atrazine.	Mayasich *et al*., 1986
Estuarine microcosm: (????? day, nominal) Nominal concentrations of 0, 15, 30, and 50 ppb	The above mentioned algae were tested together and this variable also caused a sig. (0.01 level) effect on *N. oculata* growth rate	An extension of the above described study. In addition to separate culture, the two estuarine algae were cultured together. The end result was that *P. tricornutum* dominated the cultures due to the stress of atrazine to *N. oculata* under optimum growth conditions	Mayasich *et al*., 1987

Application rate (lb ai/A) Nominal/Measured Conc.	Concentration affecting endpoint (time to effect) o percent difference from controls	Narrative of Study Trends	MRID No. Author/Year
Estuarine microcosm: (4 weeks; measured) Mean measured concentrations in water were 130 ppb for the "low" treatment and 1,200 ppb for the "high" treatment over a four week period (4 weeks; measured)	130 ppb (Week 1) o no photosynthesis 130 ppb (Week 2-4) o sign. red. in plant total biomass; no change in biomass for 3 weeks 130 ppb (Weeks 1-4) o sign.; averaged 50% red. photosynthesis of *Potamogeton perfoliatus* during the test; steady recovery after first week, but not fully recovered 1,200 ppb (Weeks 1-4) o sign.; 100% red. photosynthesis throughout the test 1,200 ppb (Weeks 2-4) o sign.; plant total biomass steadily reduced 1,200 ppb (Weeks 3-4) o sign.; 80% red. shoot density	Aquatic plants were planted and atrazine-treated sediments were added to 700-L microcosms. On Day 1.5, 93.4% of the total atrazine was dissolved in water. In addition to photosynthesis, it was demonstrated that shoot growth was relatively unaffected at 130 ppb, but total biomass was sign. reduced after 2-4 weeks. Plant biomass reductions followed a 1 week lag after photosynthesis reduction. At 1,200 ppb, plant biomass had been virtually eliminated by the end of the test. Mean shoot length in the controls declined after week 1 and after week 3 for 1,200 ppb.	45087403 Cunningham *et al*., 1984 Supplemental (raw data unavailable)
Estuarine microcosm: (22-23 days; measured) Single dose: Day 0: 30,000 ppb - nominal; Measured only Day 22 or 23: 16,400-17,700 ppb	30,000 ppb (Day 5-22) o sign. ($p \leq 0.05$) red. average ratio of no. of ramets (branches): initial no. of ramets 30,000 ppb (Day 22 or23) o sign. ($p \leq 0.05$) 46-58% red. in total above-ground biomass o sign. ($p \leq 0.05$) 18% red. in average dry weight per ramet	Experiments were conducted with seagrass, *Halodule wrightii*, examining the effect of atrazine and any interactions of salinity (15, 25, 35 ppt), light intensity (115, 140, 173 $uEm^{-2}s^{-1}$), and cropping (either cut at 4-cm or 6-cm). None of these environmental factors affected the response of the grass to atrazine.	45205101 Mitchell, 1987 Supplemental (raw data unavailable)

ii. Aquatic Field Studies (including Mesocosms and Limnocorrals)

a. Freshwater Ponds, Lakes and Reservoirs

Application rate (lb ai/A) Nominal/Measured Conc.	Concentration affecting endpoint (time to effect) o Affected Species and Life Stage	Narrative of Study Trends	MRID No. Author/Year
Freshwater Lake: Plankton (Duration 18 days) Measured = ≥90% of nominal over the test period (18 days): nominal concentrations of 0.1, 1, 10, and 100 ppb	NOEC = < 0.1 ppb o transient effects on water chemistry 1 ppb (1 week) o decreased primary production; o increased bacterial numbers o decreased in zooplankton numbers (cladocerans affected greater than copepods) 10 ppb (3 weeks) o 65% sign. ($p < 0.01$) red. in daphnid population growth (combined effect of water & algae) o 59% sign. ($p < 0.05$) red. in daphnid growth (algae) 100 ppb (3 weeks) o 92% sign. ($p < 0.01$) red. in daphnid growth (combined) o 69% sign. ($p < 0.01$) red. daphnid growth (algae)	*In situ* enclosures in a German lake were treated and monitored over 18 days. Dose-responsive reductions in chlorophyll-a and oxygen and increases in particulate organic carbon were observed at 1, 10, and 100 ppb. Within 1 week at 1 ppb, primary production decreases and bacterial number increases were observed. Zooplankton numbers then decreased, with cladocerans affected more than copepods. Additional studies at 0.1 ppb also demonstrated transient effects on water chemistry and biological parameters. Most of the parameters were recovered or were recovering within 42 days of application.	45087414 Lampert *et al*., 1989 Supplemental (raw data unavailable)

Application rate (lb ai/A) Nominal/Measured Conc.	Concentration affecting endpoint (time to effect) o Affected Species and Life Stage	Narrative of Study Trends	MRID No. Author/Year
Freshwater Pond: Plankton Treated 3 times on 7/31, 8/28 (29 days later), and 9/21/1990 (24 days later) at 5, 10, 25, 75, 200, and 360 ppb. Weekly conc. relatively constant; mean measured conc. over two months are 5, 10, 22, 68, 182, and 318 ppb (63 days; measured)	NOEC: 5 ppb (63 days) compared to controls 10, 22 and 68 ppb o up to 40% red. dissolved oxygen (Days 7-46) o up to 10% incr. pH (Days 18-63) o up to 10% red. conductivity (Days 7-53) 68 ppb o up to 78% red. copepod nauplii and no increase in nauplii at 182 & 318 ppb o diatoms appear to become the dominant phytoplankton 182 ppb o strong red. in dissolved oxygen and conductivity and strong increase in pH levels (same for 318 ppb) o up to 98% red. Cryptophyceae, *Cryptomonas marsonii* and *S. erosa/ovatata* (Days 21 to tests end) o up to 10% red. conductivity (Days 7-53) o up to 98% red. seasonal blooms of *Cryptomonas marsonii* & *S. erosa/ovatata* (Days 21 to tests end) o prevented *Mallomonas* sp. seasnal bloom (318 ppb too) o prevented the seasonal bloom of *Planktosphaeria* sp. (Chlorophyceae) after Day 30 (same at 318 ppb) o lower numbers & early seasonal decline of rotifers, *Synchaeta* sp. (same at 318 ppb) 318 ppb o up to 80% red. phytoplankton cell density (throughout test, except on Day 35) o up to 98% red. Cryptophyceae, *Cryptomonas marsonii* and *S. erosa/ovatata* (first appeared on Day 10 - Days 21 to tests end) o up to 9% incr. pH (Days 18-63) o up to 10% red. conductivity (Days 7-53) o strong red. in cell numbers of *Planktosphaeria* sp. (Chlorophyceae) after Day 30 o delays in reaching and lower peak daphnid egg ratio, and delayed peaks for numbers of young and adults	Mesocosms (1,000 L cylinders) in southern Bavaria were treated with atrazine 3 times (29 and 24 day intervals) over 63 summer days. Strongly dose-response reductions in dissolved O_2, pH, and conductivity were noted at concentrations greater than 5 ppb. Changes in oxygen concentrations at $\geq$ 10 ppb and some zooplankton populations at 68, 182, and 318 ppb reflect indirect functional links as a result of altered primary production. At 68 ppb, up to a 78% reduction in copepod nauplii was found and no increase in the number of nauplii was found at 182 and 318 ppb. At 182 ppb, threshold concentrations for direct effects by atrazine were exceeded in several phytoplankton species. Diatoms appeared to become the dominant phytoplankton at 182 and 318 ppb. One rotifer species decreased at 182 ppb and another at 318 ppb and was virtually absent from Day 18 to the end of the study. Daphnid reproduction and populations decreased at 318 ppb.	45020022 Juttner *et al*. 1995 Supplemental (raw data unavailable)

Application rate (lb ai/A) Nominal/Measured Conc.	Concentration affecting endpoint (time to effect) o Affected Species and Life Stage	Narrative of Study Trends	MRID No. Author/Year
Artificial freshwater ponds in Kansas treated with atrazine to achieve concentrations of 20 and 500 μg/L Atrazine levels measured in the water column four times during the first two months of the study: 100% of nominal at time zero (163 days; measured).	Laboratory data shows results for atrazine sensitivity tests for treated field samples: 1 ppb o sign. (0.05) 4% increase in fluorescence 5 ppb o sign. (0.05) 9% increase in fluorescence o sign. (0.05) 8% decrease in C-14 uptake 20 ppb o sign. (0.05) 30% increase in fluorescence o sign. (0.05) 12% decrease in C-14 uptake 500 ppb o sign. (0.05) 136% increase in fluorescence o sign. (0.05) 88% decrease in C-14 uptake Field pond study results: 20 ppb o sign. (0.05) 51% red. C-14 uptake (4 hr.) (Days 2-7) o sign. 42% red. phytoplankton biomass (Days 2-7) o 3% red. growth & 28% red. daphnid reproduction *Simocephalus serrulatus* correlated with food levels 500 ppb o pH red. 0.3 units lower than controls for a few weeks o dissolved O_2 generally red. 1-3 mg/L (a few weeks) o sign. 94% red. C-14 uptake (4 hr.) (Days 2-163) o usually sign. red. phytoplankton biomass (Days 2-136) o rapid, nearly complete red. in abundant *Peridinium inconspicuum*, a small dinoflagellate and rapid red. in 7+ other dominate phytoplankton sp. after 7 days o incr. in several flagellate species; mainly *Mallomonas pseudocoronata*, *Cryptomonas marssonii* & *C. erosa* o zooplankton dominance shifted to rotifers, mainly *Keratella cochlearis* after Day 31 o >50% red. in the copepod, *Tropocyclops prasinus mexicanus* by Day 14	Single treatment of two 0.045 hectare ponds each with either 20 or 500 ppb atrazine produced dose responsive changes in pH, DO and daily carbon uptake. Phytoplankton growth was reduced; population shifts were apparent at 20 and 500 ppb. Effects on phytoplankton were immediate, within 2 days, for daily carbon-14 uptake and biomass declines at both treatment levels, which is consistent with other researchers in laboratory tests. Atrazine concentrations down to 1 ppb affected photosynthesis in lab tests with phytoplankton samples from the pond. While atrazine produced direct toxic effects on just certain members of the aquatic community, their responses also affected other members of the community. At 500 ppb, one species of herbivorous zooplankton declined by more than 75% within 14 days of treatment. Subsequent laboratory tests demonstrated some atrazine resistance in phytoplankton and showed zooplankton population effects were due to loss of food (algae). Further evidence of resistance was indicated by a dominant phytoplankton species which showed less toxic responses than the same species in the control pond.	45020011 DeNoyelles *et al*. 1982 Supplemental (raw data unavailable)

Application rate (lb ai/A) Nominal/Measured Conc.	Concentration affecting endpoint (time to effect) o Affected Species and Life Stage	Narrative of Study Trends	MRID No. Author/Year
Artificial freshwater ponds in Kansas treated with atrazine to achieve concentrations of 20 and 500 μg/L	NOAEC < 20 μg/L 20 μg/L - 29% increase in turbidity. - initial depressed phytoplankton, followed by an increase in standing crop and numerical dominance of resistant species. - red. production of *Naajas* sp. and Potamogeton spp. in areas excluding carp. - increase in *Chara* - 82% reduction in total insect emergence. - 89% red. in non-predator insect emergence. - 90% red. *Labrundinia pilosella* emergence. - 50% red. in total insect species richness. - 57% red. in non-predator insect species richness. 100 μg/L - 62% increase in turbidity. - absence of periphyton on walkway supports. increase in *Chara* sp. - 83% reduction in total insect emergence. - 95% red. in non-predator insect emergence. - 96% red. *Labrundinia pilosella* emergence. - 71% red. in total insect species richness. - 85% red. in non-predator insect species richness. - 5% red. in insect species evenness. 500 μg/L - 65% increase in turbidity. - absence of periphyton on vascular plants. - absence of *Chara* sp. - 70% reduction in total insect emergence. - 85% red. in non-predator insect emergence. - 90% red. *Labrundinia pilosella* emergence. - 59% red. in total insect species richness. - 66% red. in non-predator insect species richness. - 15% red. in insect species evenness.	Two artificial Kansas ponds each (0.045 ha. and 2.1 m. deep) were treated with technical atrazine at 20 μg/L and 100 μg/L and with a 41% ai CO-OP liquid atrazine at 20 μg/L in 1981; two ponds served as controls. The ponds were treated again on 30 May 1982, but the 41% ai ponds were converted to 500 μg/L with technical atrazine. The macrophyte community in treated ponds was noticeably reduced, relative to controls, throughout the summer. For 16 sampling dates between 8 May and 28 September 1982 insect emergence was monitored in each pond with 4 emergence traps for 48 hour periods. No significant differences between ponds were found in water level, temperature or oxygen levels. Mean turbidity varied significantly among treatments (ANOVA), increasing with increasing atrazine levels up to 100 μg/L. The phytoplankton community responses to atrazine during the present study corroborate results from the 1979 study by deNoyelles *et al*. (1979). Macrophyte response also paralleled the 1979 study. The presence of live plants of the primary emergent vegetation, *Typha* spp., gradually decreased, as in previous studies, with increasing atrazine concentration both within and outside carp exclusion areas (Carney 1983, deNoyelles and Kettle 1983).	45227706 Dewey 1986

Application rate (lb ai/A) Nominal/Measured Conc.	Concentration affecting endpoint (time to effect) o Affected Species and Life Stage	Narrative of Study Trends	MRID No. Author/Year
Artificial freshwater ponds in Kansas treated with atrazine to achieve concentrations of 20 and 500 μg/L	NOAEC < 20 μg/L 20 μg/L - 60% sign. ($p < 0.05$) reduction in macrophtye vegetation at summer's end including elimination of *Potamogeton pusillus, P. nodosus*, & *Najas quadalupensis*; - 95% sign. ($p < 0.05$) red. macrophyte coverage in May, 10 months after treatment; - 96% sign. ($p < 0.01$) reduction in the number of young bluegill; - 85% sign. ($p < 0.001$) red. in the number of food items/ fish stomach; - 57% sign. ($p < 0.001$) red. in the number of prey taxa/ fish stomach. 500 μg/L - 90% sign. ($p < 0.05$) reduction in macrophtye vegetation at summer's end including elimination of *Potamogeton pusillus, P. nodosus*, & *Najas quadalupensis*; - >95% sign. ($p < 0.05$) red. macrophyte coverage in May, 10 months after treatment; - 96% sign. ($p < 0.01$) reduction in the number of young bluegill; - 78% sign. ($p < 0.001$) red. in the number of food items/ fish stomach; - 52% sign. ($p < 0.001$) red. in the number of prey taxa/ fish stomach.	Two artificial Kansas ponds each (0.045 ha. and 2.1 m. deep) were treated with 20 μg/L and 500 μg/L on 24 July and two ponds served as controls. The macrophyte community in treated ponds was noticeably reduced, relative to controls, throughout the summer. Visual estimates of the macrophyte communities in the ponds showed roughly a 60 percent decline in the 20 μg/L ponds and a 90 percent decline in the 500 μg/L ponds two months after atrazine addition. These estimates were verified by rake hauls which produced these same relative differences. The following May, 10 months after treatment, when macrophytes are normally well established in Kansas ponds, the ponds were drained. Relative to control ponds, 20 μg/L ponds had a 90 percent reduction in macrophyte coverage and the 500 μg/L ponds had a >95 percent reduction in macrophyte coverage. Differences were noted in the macrophyte species present. Control ponds contained *Potamogeton pusillus* and *P. nodosus, Najas quadalupensis*, and small amounts of *Chara globularis*, whereas the treated ponds contained mostly *C. globularis*. Significant indirect effects were found on bluegill diet and reproduction.	45202912 Kettle, de Noyelles, Jr., Heacock and Kadoum 1987 Supplemental (raw data are not available for analyses)

Application rate (lb ai/A) Nominal/Measured Conc.	Concentration affecting endpoint (time to effect) o Affected Species and Life Stage	Narrative of Study Trends	MRID No. Author/Year
Freshwater limnocorrals: (3 controls and 3 treated at nominal concentrations of 100 ppb on June 1 & July 6, 1983) Measured conc. range: 80-140 ppb after the first application, 120-165 ppb after the second application (329 days; measured)	Effects on periphyton and environmental parameters: first application: 80 - 140 ppb o no sign. effects on DO, temperature, Secchi depth, dissolved inorganic carbon (DIS), NO_3-NO_2-N), total nitrogen, and total phosphorus o periphyton dry wt. lower than controls after Day 14 at most depths; sign. (0.05) red. at a depth of 0.5 m on Day 34 and thereafter o sign. 94% red. C-14 uptake (4 hr.) (Days 2-163) o usually sign. red. phytoplankton biomass (Days 2-136) o rapid, nearly complete red. in the abundant *Peridinium inconspicuum*, a small dinoflagellate and rapid red. in 7+ other dominate phytoplankton sp. after 7 days o incr. in several flagellate species; mainly *Mallomonas pseudocoronata*, *Cryptomonas marssonii* & *C. erosa* o zooplankton dominance shifted to rotifers, mainly *Keratella cochlearis* after Day 31 o >50% red. in the copepod, *Tropocyclops prasinus mexicanus* by Day 14 second application 120 - 165 ppb o sign. (0.05) 20% red. dissolved oxygen (Days 37-137) o sign. (0.05) 33% increase in Secchi depth o sign. (0.05) 62% increase dissolved inorganic carbon o sign. (0.05) 103% increase in NO_3-NO_2-N o sign. (0.05) red. periphyton dry weight at depths of 0.5 and 1.5 m on most sampling days o sign. (0.05) red. decr. chlorophyll (19 days after second appl. (Day 54 & on some days thereafter) o zooplankton dominance shifted to rotifers, mainly *Keratella cochlearis* after Day 31 o >50% red. in the copepod, *Tropocyclops prasinus mexicanus* by Day 14	Elaboration of the 80 ppb treatment from Hamilton *et al.*, 1987. After the first application (pulse), blue-green algae were eliminated and organic matter was significantly reduced. After the second pulse, organic matter, chlorophyll, biomass, and carbon assimilation were reduced by between 36 and 67%, along with certain species of green algae. Diatom numbers were greater in treatment limnocorrals than in the control limnocorrals for nine weeks after the second pulse.	45020012 Herman *et al.*, 1986 Supplemental (raw data unavailable)

Application rate (lb ai/A) Nominal/Measured Conc.	Concentration affecting endpoint (time to effect) o Affected Species and Life Stage	Narrative of Study Trends	MRID No. Author/Year
Texas Lake Mesocosm: Measured atrazine concentrations approximately 75% of nominal (15 and 153 ppb) for first application and 150% of nominal (385 and 2,167 ppb) for the second application	Phyto- and zooplankton	A 3x3 factorial design with three conc. of atrazine (0, 15, and 153 ppb) and three conc. of bifenthrin (0, 0.039, and 0.287 ppb) applied as soil slurry in May, then again one month later but with atrazine conc. of 0, 385, and 2,167 ppb and bifenthrin conc. of 0, 0.125, and 3.15 ppb. Atrazine alone caused dose-responsive reductions in chlorophyll, turbidity, primary production, increases in nitrogen and phosphorous, and reduced levels of chlorophytes, cladocerans, copepod nauplii, and rotifers. General recovery after 14 days for atrazine alone in the first phase, but recovery not complete at sampling termination after second phase (14 days). No synergistic or antagonistic effects noted.	45020014 Hoagland *et al*., 1993 Supplemental (raw data unavailable) Duplicate check & delete this
Artificial ponds: (measured) Mean measured concentrations of 18.4, 91.5 or 114 ppb (two years data), and 314 ppb	Aquatic plants, phyto- and zooplankton	Nominal applications of either 20, 100, or 300 ppb atrazine were monitored for effect 8 weeks after June application and in the next summer. Conductivity and oxygen concentration were affected at the 100 and 300 ppb levels. Reductions in aquatic plant numbers were observed at $\geq$100 ppb in the summer after application, but no effects on microflora or fauna were observed. The year after treatment (with 10 to 30% of atrazine still in the water column), *Chara* sp. replaced *Myriophyllum spicatum* and *Potamogeton natans* at levels $\geq$100 ppb. Phytoplankton became dominated with cyanophytes and then cryptophytes as the concentration of atrazine increased. Zooplankton numbers at 100 and 300 ppb were also reduced the following year.	45020017 Neugebaur *et al*., 1990 Supplemental (raw data unavailable)

b. Freshwater Natural and Artificial Streams

Application rate (lb ai/A) Nominal/Measured Conc.	Concentration affecting endpoint (time to effect) o Affected species and life stage	Narrative of Study Trends	MRID No. Author/Year
Small Canadian first-order stream adjacent to a tiled-corn field. Atrazine of unspecified purity was applied at 4 liters per hectare on 6 June 1989. The Canadian Water Quality Guidelines (CCREM, 1987) specify a guideline of 2.0 μg/L to protect freshwater life.	Non-statistical pair-wise comparison of Total Phytoplankton counts vs sta 9, the control indicates reductions at all downstream stations with effects generally decreasing with time and distance. Downstream station 11 (2.5 km from atrazine source -sta. 5): 0.047 μg/L (range 0.004-0.2μg/L) atrazine conc. o all samples with reduced total phytoplankton counts o mean reduction of 63 % (range 6 - 97 %) o highest red. (97 %) on June 9, first sampling day o reduced 70 % in final sample on 16 Nov. Downstream station 10 (50 to 75 m from sta. 5) 0.366 μg/L (range 0.1 - 1.7 μg/L) atrazine conc. o 2 out of 11 samples exceed count at sta. 9 o mean reduction of 45 % (range +55 - 92 %) o highest red. (92 %) on June 9 o reduced 47 % in final sample on 16 Nov. Downstream stations 6 & 7 (a few meters from sta. 5) 0.81 (0.17 - 1.89) and 0.05 (0.001-0.224) μg/L, resp. o 1 out of 9 samples at sta. 6 exceeds count at sta. 9 o mean reduction sta. 6 of 53 % (range +68 - 99) o mean reduction sta. 7 of 66 % (range 3 - 95) o highest red. (99 and 93 %, resp.) on July 21 o red. 45 & 27 %, resp. in final sample on 16 Nov. Ditch (station 5) receiving waters from the 4 tile outlets: 2.62 μg/L (range 0.211 - 13.9 μg/L) atrazine conc. o mean reduction of 79 % (range 46 - 99 %) o highest red. (92 %) on 3 dates, June 23 - July 21 o reduced 51 % in final sample on 16 Nov.	Atrazine concentrations up to 20.39 μg/L (sta. 4) in field tile water, 13.9 μg/L (sta. 5) in receiving ditch and 1.89 μg/L in a small stream (sta. 6) were measured in New Brunswick, Canada in a rural headwater basin of the Petitcodiac River. The fist-order stream flowed parallel to an 8-hectare sub-surface tile-drained field of silage corn. The field was divided into 4 plots and each drained separately into a small canal and into the stream. Water, phytoplankton and zooplankton were sampled at 15-day intervals at 11 sampling sites during the growing season. Total phytoplankton numbers in downstream samples were consistently much less than those from upstream (control) samples during the period of low flow and higher atrazine levels (during the summer). Diatoms dominated the phytoplankton community. Occurrence of other algal species were erratic between stations and over time. Zooplankton numbers were too low to discern trends, but downstream samples were consistently lower in individuals than control samples.	45020008 Lakshinarayana, O'Neill, Johnnavithula, Leger and Milburn 1992 Supplemental (Replication of samples and statistical analyses were not made)

Application rate (lb ai/A) Nominal/Measured Conc.	Concentration affecting endpoint (time to effect) o Affected species and life stage	Narrative of Study Trends	MRID No. Author/Year
Artificial stream test: (14 day; measured) Simulated pulsed- exposures; 5 μg/l atrazine on Day 1 and gradually diluted until only about 1 μg/L on Day 7	5 μg/L to about 1 μg/L on Day 7 o atrazine concentrations: Day 1 Mean conc. 4.74 5 3.56 10 1.20 14 1.19 Possible atrazine effect: o 58 to 126 fold increase sign. ($p<0.05$) in number of emergent insects on Days 3, 5 and 7; treatment numbers were equal to or greater than controls in all samples No statistical effects found in atrazine treatments on: o periphyton growth measured as chlorophyll a levels; chlorophyll a levels decreased gradually in all samples (treatments & controls) over time, "may have masked an effect of atrazine" o indirect effects on function or taxonomic composition of benthic community structure	A community of benthic, stream invertebrates from the Patrick Brook in Hinesburg, Vermont, located in the LaPlatte River watershed. Microbial community growth was incubated for 2 weeks this substrate was placed in 10 x 10 x 7 cm polyethylene boxes and placed in the stream for invertebrate colonization for 3 weeks in July 1993. During the same 3-week period glass slides were placed in the stream for algal settling and growth. Four benthic invertebrate boxes and 9 periphyton slides were randomly placed in each of six replicate tanks. The flow rate was calculated as 20.8 L/min. throughout the test. After a 24-hour equilibration period, treatment at 5 μg/L atrazine was introduced to 3 replicates and 3 controls. On Day 3, about 15 percent of the water was replaced; on Days 6 and 7 water replacements were 50 percent each day; about 15 % was replaced on Day 11 during the 14-day test. "Dewey (1986) also observed herbivorous insects emerging earlier from artificial ponds treated with 20 μg/L atrazine compared to controls. Dewey suggested that the changes she saw were the indirect effect of atrazine exposure, which had reduced the amount of food available to herbivorous insects."	45087411 Gruessner and Watzin 1996 Supplemental (raw data unavailable for statistical analyses)
Artificial stream tests: (14 day; measured) One dose and recirculation; two atrazine levels (40.8% ai): 15.2 $\pm$ 1.4 and 155.4 $\pm$ 1.4 μg/l atrazine on Day 1; 17.5 $\pm$ 1.2 and 135.0 $\pm$ 4.5 μg/L on Day 28 Interaction test with alachlor discussed under the section on pesticide interactions.	15.2 μg/L (initial atrazine concentration): o 45% red. in benthic algal biovolume after 1 week sign. ($p \leq 0.05$); o 35% red. in benthic algal biovolume after 2 weeks non. sign. ($p \leq 0.05$); o 45% red. in benthic algal biovolume after 4 weeks sign. ($p \leq 0.05$). 155.6 μg/L (initial atrazine concentration): o 45% red. in benthic algal biovolume after 1 week sign. ($p \leq 0.05$) o 50% red. in benthic algal biovolume after 2 weeks sign. ($p \leq 0.05$); o 57% red. in benthic algal biovolume after 4 weeks sign. ($p \leq 0.05$). Time-dependent analyses showed sign. ($p = 0.0083$) reduction in algal biovolume treated with both 15.2 and 155.6 μg/L atrazine throughout the test, but no sign. ($p = 0.3629$) difference between 15.2 and 155.6 μg/L levels.	A benthic mud community of epipelic algae were collected from various locations of Wahoo Creek and acclimated for 6 weeks prior to atrazine treatments. Stream water came from Wahoo Creek on March 25, 1993. Wahoo Creek is a third-order, sediment-dominated Nebraska stream draining primarily agricultural land and subject to major runoff events. Each model stream was constructed from a 114-L oval-shaped plastic tub and lined with two-layers of 4-mil clear plastic. Stream velocities ranged from 0.05 to 0.1 m/sec. in the sending segment and 0.01 to 0.05 m/sec. in the returning segment. Lighting was 12 hour/12 hour light/dark cycle. To replace evaporated water, stream water from the transport tank was mixed for 24 hours prior addition to each stream. Epipelic algae were sampled immediately before herbicide atrazine addition, 24 hours after addition, and after 1, 2 and 4 weeks. Algal samples were analyzed for cell density, cell biovolume and the relative abundance of 6 dominant taxa.	45020002 Carder & Hoagland 1998

Application rate (lb ai/A) Nominal/Measured Conc.	Concentration affecting endpoint (time to effect) o Affected species and life stage	Narrative of Study Trends	MRID No. Author/Year
Natural Tasmanian stream: (2 weeks to 7 months: measured concentrations) Forests aerially sprayed once at either 3 or 6 liters ai per hectare of Gesaprim: peak of 22 ppb; median conc. of 2.5 ppb for the 2 weeks after application	Atrazine levels in 24 Tasmanian streams averaged 2.85 μg/L (range< 0.01-53 mg/L). In forestry areas, the mean stream conc. was 2.00 (<0.01-8.9) μg/L with 35% below the detection limit of 1.0 μg/L. Spray drift into the stream appeared the same as in the treated forest as estimated by spray-droplet deposits on wood. 22 μg/L: o sign. increase ($p < 0.01$) in daytime invertebrate drift at site 2, 12 hours after treatment o site 3 also showed an increase in daytime invertebrate drift on day of treatment, but not statistically sign. ($p > 0.05$) o sign. ($p<0.001$) increase in night drift in number of hydroptylid larvae on days 1, 2, 4, and 9 o sign. ($p<0.001$) increase in night drift in number of hydropsychid larvae on days 2, 4, and 9 The effects of invertebrate drift at site 2 were associated with increased spray drift, during the 12 hours immediately following application. Poor habitat and limited taxa at site 2 precluded drift analyses on specific taxa. o no sign. affect on mean densities of benthic invertebrates, number of taxa or taxa proportions o 71% sign. ($p<0.01$) increase in trout population at site 2 sustained over four months o no sign. effect on fish mortality or physiology	Tasmanian stream, Big Creek, with a catchment area of 36 km^2 was studied for atrazine aerially sprayed on two forest areas of 20 and 66 hectares, at rates of 3 and 6 kg ai/ha on 13 and 14 October 1987, respectively. Three sampling sites were picked: Site 1 above the 2 plantations, sites 2 and 3 were just below each plantation. Each site consisted of an upstream riffle for invertebrate samples and an area 100 m downstream for sampling brown trout (*Salmo trutta*). Atrazine levels in 174 water samples from 44 sites from 24 streams averaged 2.85 μg/L (range< 0.01-53 mg/L). Only 9.6% of samples were below detection limit (0.1μg/L) and only 24 % were below 1.0 μg/L. In forestry areas, the mean stream conc. was 2.00 μg/L (range <0.01-8.9 μg/L) with 35% below the detection limit of 1.0 μg/L. The initial measured concentration in Big creek was 22 μg/L, 2 weeks later atrazine averaged 2.5 (range 1.2-4.6) μg/L, and over the following 2 months ranged from 0.01 to 0.09 μg/L. Atrazine levels in a small seepage draining the 2 plantations range 0.8- 68 μg/L over the next 2 months. Site 2 sediments ranged from 1.6 to 22 μg/kg wet weight two weeks after spraying. No fish mortality or behavioral changes were recorded during applications. However, brown trout movement within the application area was significantly different (increased) than the upstream control movement. No changes in trout physiology were observed.	45020003 Davies *et al*., 1994 (Species are not native to North America; Raw data unavailable for statistical analyses)

Application rate (lb ai/A) Nominal/Measured Conc.	Concentration affecting endpoint (time to effect) o Affected species and life stage	Narrative of Study Trends	MRID No. Author/Year
Artificial stream in laboratory Technical Atrazine: 98.2% Experiment 1: Constant 12-day exposures at 0, 24 & 134 μg/L atrazine Experiment 2 involved pulsed exposures of 4 herbicides mixed together at nominal concentrations of: Atrazine at 135 μg/L; Alachlor at 90 μg/L; Metolachlor at 200 μg/L; Metribuzin at 20 μg/L. Full concentrations on Days 8 & 9, halved on Days 10 & 11, and discontinued on Day 12.	Constant 12-day exposure tests (Days 8-17) 10 and 25°C: o 24 μg/L: - 24% red. sign. ($p<.001$) in ash-free dry wt. at 25°C - 30% red. sign. ($p<.01$) in chlorophyll a at 25°C o 134 ug/L: - 47% red. sign. ($p<.001$) in ash-free dry wt. at 10°C - 31% red. sign. ($p<.001$) in ash-free dry wt. at 25°C - 44% red. s ign. ($P<.001$) in chlorophyll a at 25°C - 30% red. s ign. ($P<.01$) in chlorophyll a at 10°C Nutrient uptake was affected more by the 15°C difference, than the atrazine concentrations. Raw data were absent and statistically analyses could not be assessed. As cited: - 35% red. N uptake at 134 μg/L at 10°C; not sign. - 25% red. N uptake at 134 μg/L at 25°C; not sign. - 31% red. silica uptake at 134 μg/L at 10°C; not sign. - 58% red. silica uptake at 134 μg/L at 25°C; not sign. - 14% red. P uptake at 134 μg/L at 10°C; not sign. - 8 % red. P uptake at 134 μg/L at 25°C; not sign.	Six artificial streams consisting of a 7.5 cm OD x 123 cm long Pyrex glass tube were tested concurrently for pesticide effects on *aufwuchs* productivity and nutrient uptake (NO_2, NO_3, phosphorus PO_4 and silica were tested after an 7-day colonization period with natural waters from a third order stream in the Sandusky Basin, Ohio. Two experimental designs (continuous and pulsed exposures) were tested under constant lighting, flow rates of 7.8 mL/min. natural creek water and 1.0 mL/min. nutrient water for 20-day periods. Experiment 1. Two "streams" were exposed to continuous nominal atrazine concentrations of 0, 50 and 200 μg/L at 25°C and then repeated at 10°C on Days 8-17. Experiment 2. Three streams were treated to pulsed exposures of a mixture of four herbicides. These results are not relevant to the risk assessment for atrazine.	45020007 Krieger, Baker and Kramer 1988 Supplemental (The solvent methanol 0.00057% v/v was not added to controls; raw data unavailable for statistical analyses)
Two artificial model streams in laboratory continuously exposed for 30 days with 60-day recovery period and repeated 4 times in one year. Nominal concentration of 25 μg/L technical grade atrazine dissolved in DMSO; atrazine concentrations in streams were not measured.	25 μg/L Atrazine: After one year of 4 treatment and recovery cycles, it was reported that the treatment did not have any significant or lasting effect on macroinvertebrate population structure, periphyton standing biomass or rates of primary production and community respiration. Two out of 200 statistical tests showed significant effects for atrazine treatment: equitability ($p < 0.029$) during Winter , month 3, and taxa/sample ($P < 0.001$) during the Spring, month 3. Macroinvertebrate drift in streams increased abruptly upon injection in both controls and treatments which was attributed to the solvent rather than to atrazine. Initial drift samples were collected only in the autumn and summer. Drift in the summer samples were "substantially higher" in the atrazine-treated streams than in the DMSO-treated control. Pulses in the number of drifting organisms following toxicant/solvent injection were primarily due to *Baetis* mayflies.	Continuous-flow stream treatment for 30 days at 25 ppb, followed by 60 days of no treatment, and repeated 4 times for one year in artificial, 3.96 m.-long concrete-lined streams inside a laboratory. Invertebrate populations were introduced by colonization from incoming drift with water flowing from a natural creek over a one year period before treatment. Atrazine was injected into the flowing water for periods as described above. Benthic invertebrate populations as follows: two samples (10.2-cm diameter cores) during pretreatment were collected at 45-day intervals for 1 year. Three post-treatment samples were made every 30 days. 24-Hour invertebrate drift samples were collected were collected on days 1, 5, 10, 20, and 29 during treatment and on days 14, 42 and 60 during recovery periods. Dry and ash weights of periphyton standing crop on four 25 x 75 mm glass slides were sampled at 4-day intervals for 28 days before and after each treatment. 24-Hour gross primary production and community respiration rates (O_2 levels) were measured during the autumn on days 2, 4, 8, 15, 24 and 29 after treatment and on days 20, 42, 54 and 60 during the recovery period.	45020009 Lynch *et al*., 1985 Supplemental DMSO is not an acceptable solvent, because it accelerates the movement of chemicals across cell membranes. As such it represents a worst case exposure. Raw data were not available for statistical analyses. Three or four samples are considered inadequate for field samples to show anything short of severe effects.

Application rate (lb ai/A) Nominal/Measured Conc.	Concentration affecting endpoint (time to effect) o Affected species and life stage	Narrative of Study Trends	MRID No. Author/Year
Artificial model streams in laboratory: (7 days; nominal) Single applications to spring water; Brazos, Texas. Nominal test concentrations: 0, 100, 1000 and 10,000 μg/L	o statistically significant reductions (*) in net stream community productivity compared to controls: Day 1 Day 3 Day 7 100 μg/L 736 %* 117 %* 34 % 1000 μg/L 1367 %* 227 %* 119 %* 10,000 μg/L 1716 %* 264 %* 135 o sign. ($p<0.02$) increase in *Nitzschia* cell numbers o no significant effect on other dominant algal groups o no significant effect on community respiration rates o no significant effect on conductivity or alkalinity	Four replicate recirculating artificial streams per treatment. Each stream (2.43 m long, 12.5 cm wide and 6 cm deep) was lined with polyethylene plastic and a single layer of gravel. Water from Minter Spring is a nearly anoxic and has a constant temperature (21°C). The flow rate was about 5 cm/sec. The principal algae genera were *Anabaena, Nitzschia, Rhopalodia* and *Navicula*. Five weeks for colonization of benthic algae on glass slides. Each stream received a single treatment which was recirculated. Nominal conc. were 0, 0.1, 1.0 and 10 μg/L. Endpoints were net community productivity, respiration rate, cell numbers of dominant species, conductivity and alkalinity.	45020010 Moorhead and Kosinski 1986 Supplemental (raw data unavailable)
Not assayed, nominal conc. of 5, 25, and 125 ppb	Snail (*Lymnaea palustris*)	Snails exposed to one time dosing in mesocosm of either 5, 25, or 125 ppb and monitored for 12 weeks, no affect on growth, fecundity, or saccharide metabolism.	45020013 Baturo *et al*., 1995
Mean concentrations over two months of 5, 10, 22, 68, 182, and 318 ppb	Phyto- and zooplankton	Mesocosms in Bavaria were treated with atrazine 3 times over 3 summer months. Dose responsive reductions in dissolved oxygen and pH were noted at concentrations greater than 5 ppb. Substantial biological effects were generally noted at concentrations $\geq$182 ppb. Some effects on copepod nauplii were noted at 68 ppb. Diatoms appeared to become the dominant phytoplankton.	45020022 Jüttner *et al*., 1995 Supplemental (raw data unavailable)
Nominal concentrations of 20, 100, 200, and 500 ppb. Measurements bi-weekly or monthly but results based on nominal concentration	Phytoplankton	Results of single species assays, microcosm, and pond studies were compared. Carbon fixation was used as the end-point for all three study types. Laboratory results with eight algal species ranged from 37 to 308 ppb for carbon uptake inhibition EC_{50} values. Microcosm EC_{50} values ranged from 103 to 159 ppb. The mean pond EC_{50} was 100 ppb for carbon uptake and 82 ppb for chlorophyll-a inhibition. Authors stated that multiple laboratory studies or a microcosm study represent(s) entire ecosystem functional effects.	45020015 Larsen *et al*., 1986 Supplemental (raw data unavailable)

Table 1 - cont. Atrazine Field or Mesocosm Studies.

Application rate (lb ai/A) and/or Nominal/Measured Concentration	Affected Species and Life Stage	Percentage Affected in Comparison to the Control and Type of Effect	Author/ Year
Measured = nominal (50 ppb) at time zero, declined to 40% of nominal after 8 weeks	Aquatic plants and fish	Atrazine and esfenvalerate were applied together in mesocosms to examine possible synergism (reduction of macrophytes leading to extension of insecticide residues and increased fish mortality). Combinations of 50 ppb atrazine and esfenvalerate at 0.25 to 1.71 ppb did not result in synergism. However, *Chara* sp. totally replaced the co-dominant *Naja* sp. six weeks after application.	Fairchild *et al*., 1994
Day 1 measured concentrations of 80, 140, or 1,560 ppb	Periphyton	Applications were made to *in situ* limnocorrals in June (140 and 1,560 ppb) or June & July (80 ppb) and colonized periphyton slides were submersed in August and monitored for either 56 days (140 and 1,560 ppb) or 210 days (80 ppb). Trends from both years included a shift from a chlorophyte to a diatom community, and a development of some atrazine "resistant" colonies. Community production was reduced by 21% and 82% at the 140 and 1,560 ppb levels, respectively, and certain algae were reduced up to 93%. All biotic measures indicated reduced growth, with cell densities lagging productivity. All parameters except species richness returned to control levels prior to 56 days after first or second applications.	45020020 Hamilton *et al*., 1987 Supplemental (raw data unavailable)
Day 1 measured concentration of 80 ppb (two applications of 100 ppb made 35-days apart)	Phyto- and zooplankton	Elaboration of the 80 ppb treatment from Hamilton *et al.*, 1987. Two weeks after first application, significant declines in multiple species of green algae were observed, whereas crypto- and dinoflagellates either increased or stayed the same. Low population densities persisted for 114 days after the second application. Average of ≈25% fewer species in atrazine limnocorrals. Control and treated values equilibrated within one year of treatment. Only two zooplankters were affected (after the second application). A MATC was suggested to be between 100 and 200 ppb.	Hamilton *et al*., 1988

Table 1 - cont. Atrazine Field or Mesocosm Studies.

Application rate (lb ai/A) and/or Nominal/Measured Concentration	Affected Species and Life Stage	Percentage Affected in Comparison to the Control and Type of Effect	Author/ Year
Measured after a single dose at 1,100 ppb - Day 1: 200 ppb, 55 days later: 60 ppb	Phytoplankton	Treatment related reductions in oxygen, and pH, and increases in conductivity were noted after atrazine treatment, with oxygen and pH returning to control values within 30-40 days. At 26 days after dosing, 78 algal cells/mL were present in the control and no cells were present in the treated enclosures. Diversity was also reduced the month after application.	45020016 Lay *et al*., 1984 Supplemental (raw data unavailable)
Not assayed, nominal concentrations of 50,000, 100,000, and 150,000 ppb	Autotrophs	Primary production and respiration was monitored in a freshwater ecosystem in India. Net productivity in water samples was reduced by 23% and 73%, respectively, at 50,000 and 100,000 ppb, in comparison to control values, and was negative in the 150,000 ppb treatment group.	Piska and Waghray, 1990

c. Marine and Estuarine Waters

Application rate (lb ai/A) Nominal/Measured Conc.	Concentration affecting endpoint (time to effect) o Affected Species and Life Stage	Narrative of Study Trends	MRID No. Author/Year
Marine Mesocosm: Open Ocean: Phytoplankton: (15 days; measured conc.) Measured = nominal at time zero, concentrations of 0.12, 0.56, and 5.8 ppb	0.12 ppb (differences compared to controls) o sign. lower pH levels (Days 5-14); indicative of reduced photosynthesis o higher dissolved organic nitrogen (DON) (Days 6-11) o up to 50% red. primary production (Days 3-11) o up to 60% red. particulate carbohydrates (Days 5-15) o up to 70% red. chlorophyll (Days 4-15) 0.56 ppb o sign. lower pH levels (Days 5-13) o incr. total dis. organic phosphate (DOP) (Days 3-14) o higher DON (Days 5-15) o up to 50 % red. primary production (Day 3-13) o up to 85% red. particulate carbohydrate (Days 5-15) o up to 80% red. chlorophyll (Days 4-15) 5.8 ppb o sign. lower pH levels (Days 5-11) o up to 200% increase in total DOP (Days 3-14) o up to 200 % increase in total DON (Days 2-15) o up to 50% red. in primary productivity (Days 3-7) o up to 60% red. in partic. carbohydrates (Days 5-15) o up to 30% red. in chlorophyll conc. (Days 4-15)	Mesocosms (2 m^2) inoculated with the diatoms *Thalassiosira punctigera*, *T. rotula*, *Nitzschia pungens* and *Skeletonema costatum* and a prymnesiophtye, *Phaeocystis globosa.* evidenced a dose-responsive elevation in dissolved nitrogen and phosphorous and reduction in primary production at 0.12, 0.56, and 5.8 ppb. The NOEL was reported to be <0.12 ppb. Atrazine at concentrations at 0.12, 0.56 and 5.8 ppb, adversely effects primary production of unicellar algal species at certain growth phases and causes increases in "excretions" of dissolved organic nitrogen and phosphorus. "Excretions" may be caused by atrazine stress on cells or lysis of cells.	45020021 Bester *et al.*, 1995 Supplemental (raw data unavailable)
Nominal applications of 0.4, 4.5, or 45 lb ai/A	Salt marsh edaphic alage	Elaboration of Plumley *et al.*, concerning the carbon uptake for algae in the top 0.5 cm of enclosure sediment. Carbon fixation was significantly reduced at the 0.45 and 4.5 lb ai/A treatment levels for 16 days and at the 45 lb ai/A treatment level for 42 days.	45087406 Plumley and Davis, 1980

f. Reported Ecological Incidents

The Ecological Incident Information System (EIIS) maintained by EFED has a total of 61 reported incidents of varying certainty for atrazine. Twelve incidents were classified as "Unlikely" and two were "Unrelated." In only one case, a cotton use, was fish carcasses analyzed for atrazine residues. The shad and carp tested positive for atrazine in the Richland, Louisiana incident (I004021-004). Most incidents involved effects on fish kills. Other non-target organisms affected include grasses and on occasions: corn, fruit trees, ornamentals, garden, raspberry, oats, cats, chicken, a goat, black snake and a cave amphipod.

Four incidents are listed as "Highly Probable" including a home/lawn use incident (# I001910) and a corn use incident affecting 100 bass and 100 bream (# B000163-001) resulting from registered use. Two home/lawn incidents affecting grass were concluded to be misuse/accidental (# I005579-001, I005132-001). Seventeen incidents are listed as "Probable" including 7 corn incidents (I007372-002, all bluegill and largemouth bass; I000116-002, thousand bluegill and thousand largemouth bass, I001081-001, 10 feet of grass and 600 catfish; I001081-002, bluegill and bass; B000150-003, bass and bluegill; I004697-084, fish; I000636-032, bluegill and a few crappie), 4 agricultural use incidents (I001099-001, grass; I001041-001, fescue grass; I003826-006, not reported; I005895-074, not reported), 1 home/lawn incident (I000941-078, grass), 1 field incident (I005595-001, unknown) and 1 unreported source (I000358-004, fruit trees and garden). Two probable incidents were classified as misuse from corn use (I005879-003, pears, raspberry and oats; I007371-013, grass and ornamentals).

Twenty-six incidents were reported as "Possible" including 12 incidents affecting fish (i.e., bluegill (3 incidents), catfish (2), bass (2), carp (1), quillback carpsucker (1), carp (1); redhorse (1), bream (1), garfish (1), minnow (1), perch (1), unspecified fish (2); cave amphipod (1), corn (4), grass (4), trees (2), plants (1), cat (1), chicken (1), goat (1), and unreported (3).

Given the low toxicity of atrazine to fish, aquatic invertebrates and mammals, the reason for the frequency of effects on these organisms is uncertain. About 60 percent of the reported fish kills listed under atrazine in the incident record occur during the Spring when atrazine is applied, soils are saturated and heavy rainfall is frequent. Heavy runoff may carry atrazine, other pesticides and organic loads into surface waters. The high volume and wide-spread use of atrazine increases the probability of co-occurrence of fish kills with atrazine applications. There are some scenarios which may explain atrazine induced fish kills as well as causes unrelated to atrazine use.

Three plausible scenarios could exist in which atrazine applications may be responsible for the fish kills. First, atrazine concentrations in surface waters from runoff and/or spray drift may be much higher in shallow water adjacent to treated fields than estimated by EFED or found in monitoring studies. Second, atrazine in surface water may kill aquatic plants and the decaying process of dead plants may lower dissolved oxygen to levels too low for fish survival. Third, atrazine is reported to increase the toxicity of organophosphate insecticides, such as

chlorpyrifos, and a number of other pesticides which may have been applied earlier to atrazine-treated crops or applied in other fields upstream in the watershed.

Possibilities also exist that other causes, not atrazine, may be responsible for some or all of the reported atrazine incidents. Heavy organic loads consume oxygen from the water as the organic matter oxidizes, thereby causing low dissolved oxygen levels which may cause fish to suffocate and die. Other pesticides in the watershed killed the fish as the water flowed past atrazine-treated fields. Since limited information is available in the atrazine incident records, such as water and tissue analyses, conclusions of responsibility would appear to be uncertain and the result of coincidence with little evidence for cause and effect.

g. Effects of Environmental Factors and Life-Stage on Aquatic Atrazine Toxicity

1. Interaction Effects on Atrazine Toxicity to Plants

Some intra-laboratory studies suggest that atrazine toxicity is affected by some environmental parameters, such as temperature, light intensity and salinity levels. Mayer *et al*. (1998) concluded that a temperature difference of 1°C will cause a difference in algal growth rate in the range of 7 to 9 percent at the typical rate increase for 10°C temperature increase (Q_{10}) of 2 to 2.3.

In general, the toxicity of pesticides increase with increasing temperature. Mayasich, Karlander and Terlizzi, Jr. (1986) tested two algal species in 27 combinations of temperature (15, 20 and 25°C), light intensity (0.208, 0.780 and 1.352 mW/cm^2) and atrazine concentrations of 0, 50 and 100 μg/L) for 7-day periods. Toxic effects of atrazine on *Nannochloris oculata* growth rates were significantly ($p \leq 0.01$) dependent on both temperature and light intensity as determined by the 3-way interactions. Atrazine toxicity increased to *N. oculata* with both increasing temperature and increasing light intensity, except at 15°C and 1.352 mW/cm^2 where growth was intermediate. Previous results yielded a similar anomaly and it suggest that 15°C is near the lower limit for growth of this algal species. With *Phaeodactylum tricornutum*, growth rates were significant ($p \leq 0.01$) for light intensity and atrazine concentrations and was significant ($p \leq 0.05$) for temperature, but only light intensity was significantly ($p \leq 0.01$) related to an increase in atrazine toxicity. Atrazine toxicity was highest at the lowest light intensity. "The response of *P. tricornutum* to atrazine at light intensities of 0.780 and 1.352 mW/cm^2 is probably a reflection of primary effectsonly while at 0.208 mW/cm^2 light intensity includes secondary effects" (Mayasich *et al*., 1986). With respect to the insignificant effect of temperature on growth, Ukeles (1961) and Fawley (1984) found that the growth of *P. tricornutum* was unchanged by temperatures in the range of 14 to 24°C and 14 to 25°C, respectively.

Mayasich *et al*. (1987) repeated the above algal study with lower atrazine concentrations (0, 15, 30 and 50 μg/L and fewer temperatures (15 and 25°C) and light intensities (0.208 and 1.352 mW/cm^2) in unialgal and bialgal assemblages. Generally *Phaeodactylum tricornutum*'s presence significantly ($p \leq 0.01$) depressed the growth of *Nannochloris oculata*, but it did not

alter the magnitude of the responses to temperature, light intensity or atrazine concentrations. In contrast, the presence of *N. oculata* generally resulted in significant ($p \leq 0.01$) enhancement of *P. tricornutum* growth. The bialgal assemblage produced magnitudes of interactions between temperature and light intensity and temperature and atrazine were both significantly ($p \leq 0.01$) greater for *N. oculata*. *P. tricornutum* dominated the assemblage over all concentrations of atrazine under simultaneously low levels of temperature (15°C) and light intensity (0.208 mW/cm^2). At simultaneous high levels of temperature and light intensity and the absence of atrazine. *P. tricornutum* and *N. oculata* tended to be co-dominant. At increased atrazine concentrations, *P. tricornutum* became the dominant of the two algal species. The authors concluded that the enhanced sensitivity of *N. oculata* to atrazine relative to that exhibited by *P. tricornutum* posed threat to the diversity and structure of natural phytoplankton populations. Thus, a nutritious algal species for larval oysters (Dupry, 1973) is replaced by what is considered to be a poor food source for larval bivalves (Walne, 1970).

Mayer *et al*. (1998) tested the effect of four main environmental factors on the toxicity of atrazine to the green alga *Selenastrum capricornutum* in 3 day tests. The four factors tested were light intensity (44 and 198 $\mu E/m^2$), temperature (16 and 26°C), nitrogen source (NH_4+ and NO_3-) and pH (7.6 and 8.6). Temperature influenced growth only indirectly by interacting with light intensity. Algal growth measured as the atrazine EC_{50} values was marginally reduced under low light intensity at high and low temperatures (158 and 159 $\mu g/L$, respectively versus the atrazine control, 164 $\mu g/L$). High light intensity at the low temperature reduced the toxicity of atrazine to the alga by about two fold (LC_{50} 300 $\mu g/L$) while high light intensity and high temperature reduced the toxicity of the atrazine by about 118 fold (LC_{50} 191 $\mu g/L$). Nitrogen source and pH had no significant effect on atrazine toxicity affecting algal growth rates.

The above studies indicate that the toxicity of atrazine to plants can be affected by environmental parameters, but differences in those effects occur depending on the algal species. Hence, increases in temperature may increase, decrease or have no effect on atrazine toxicity to algal growth. Light intensity generally has the stronger effect on atrazine toxicity to algal growth and may, short of the point of photo-inhibition, increase the toxicity of atrazine. Nitrogen source and pH do not have any effect on the toxicity of atrazine to algae.

2. Interaction Effects on Atrazine Toxicity to Aquatic Animals

Some intra-laboratory studies suggest that atrazine toxicity to aquatic animals is affected by environmental parameters, such as water hardness, salinity and differences in the life-stages of organisms.

High levels of water hardness usually reduce the toxicity of pesticides. Intra-laboratory studies on two fish species provide comparative LC_{50} values for two levels of water hardness (Birge, Black and Bruser, 1979). Embryo-larval rainbow trout were exposed to atrazine for 27 days at water hardness levels of 50 and 200 mg/L and produced LC_{50} values of 0.66 and 0.81 mg/L, respectively. The test with channel catfish at the same water hardness levels for 8 days and yielded LC50 values of 0.22 and 0.23 mg/L. With rainbow trout embryo-larvae, the soft water

increased toxicity by about 19 percent, while the LC_{50} values for embryo-larval catfish were the same. It is uncertain, if the shorter exposure period, yolk sac or differences in species sensitivity, account for the difference in water hardness effects between embryo-larvae of channel catfish and rainbow trout.

Salinity effects at 5, 15 and 25 g/L on the toxicity of atrazine are opposite for the estuarine fish larvae, sheepshead minnow and the copepod nauplii, *Eurytemora affinis* (Ziegenfuss, Anderson, Spittler and Leichtweis, 1994). The 96-hour LC_{50} values (16.2, 2.3 and 2.0 mg/L) for sheepshead minnow consistently increased with increasing salinity. In the case of the copepod nauplii, the 96-hour LC_{50} values (i.e., 0.5, 2.6 and 13.3 mg/L) consistently decreased with increasing salinity. The consistency of the two data sets suggest that salinity effects the toxicity of atrazine. Statistical tests for both species indicate significant differences between the LC_{50} valves at 5 and 25 g/L, but not at 15 g/L. The authors concluded that the two species may be more physiologically effective in metabolizing and mitigating toxic effects of atrazine at various salinities. The increase in LC_{50} values for rainbow trout and sheepshead minnow are consistent for increasing water hardness and increasing salinity.

For many pesticides, the earlier life-stages are normally more toxic to organisms than later life-stages. Contrary to most pesticides, the aquatic toxicity data for toad and frog tadpoles suggest that the late stages are more sensitive to atrazine than early tadpole stages (Howe *et al*., 1998). The late stage of the American toad tadpole is about 2.5 times more sensitive to atrazine than the early stage (10.7 versus 26.5 mg/L). For the northern leopard frog tadpoles, the later stage is about 3.3 times more toxic than the early tadpole stage (14.5 versus 47.6 mg/L).

The above studies suggest that decreases in water hardness and salinity can increase the toxicity of atrazine to fish, but increasing salinity may mitigate atrazine toxicity to copepods. Life stages show differences in sensitivity to atrazine. The later stages in frog and toad tadpole development show an increased sensitivity to atrazine over early tadpole stages.

h. Pesticide Toxicity Interactions

1. Plants

A number of authors have reported toxic interactions between atrazine, its dealkylated degradates and other pesticides. Synergism between atrazine and a number of other pesticides has also been reported in aquatic organisms, particularly with organophosphate insecticides, a carbamate insecticide and other herbicides.

In 1974, Putnam and Penner reported on the effects of interactions of herbicides on higher plants. Atrazine was cited in test combinations with 5 herbicides, 2 insecticides and a fungicide. Synergistic effects (i.e., increased toxicity higher than additivity) was identified in 6 out of the 8 test combinations. Atrazine was synergistic with 4 herbicides (i.e., 2, 4-D (oil), paraquat, EPTC, and alachlor) and 2 insecticides (i.e., diazinon and fensulfothion). Atrazine

test combinations with dalapon, a herbicide, and dexon, a fungicide, showed antagonistic interactions.

Torres and O'Flaherty (1976) report additive toxicity of atrazine with simazine at concentrations of 1.0 ug/L and 1 mg/L for *Chlorella vulgaris*, *Stigeoclonium tenue*, *Tribonema* sp., *Vaucheria geminata*, and *Oscillatoria lutea*. Additive toxicity of malathion with atrazine was found in *Chlorella vulgaris*, but could not be assessed with other species, because malathion produced total inhibition of chlorophyll production at 1 ug/L or greater concentrations. At 1 and 1,000 ug/L, pesticides mixtures increased toxicity from 2.4 to 100 percent over the toxic levels of atrazine alone. Mixtures of these pesticides at concentrations of 0.1 and 0.5 ug/L usually enhanced the production of chlorophyll.

Stratton (1984) also tested the most sensitive algal species, *Anabaena inaequalis*, with mixtures of atrazine and its two most toxic degradates, deethylatrazine and deisopropylatrazine. Cell count results indicate that combinations of atrazine/deethylatrazine (1.8) and atrazine/deisopropylatrazine (1.3) are synergistic and deethylatrazine/deisopropyl-atrazine mixtures are additive (1.03). For photosynthesis, results after 3 hour exposures indicate that all mixture combinations for these three chemicals are antagonistic (0.8, 0.86, and 0.89).

Burrell *et al*. (1985) reported 11-day interactions between algal populations and between algal populations and pesticides. Population interactions showed that *Chlorella vulgaris* inhibited population growth of *Ankistrodesmus braunii* by 32 percent. The addition of the bacterium, *Chromobacterium violaceum*, added to the algal mixture further inhibited population growth of *A*. *braunii* by an additional 17% and bacterial growth was stimulated, but the bacterium had no effect on *Chlorella* populations. The combined effect of the mixtures of atrazine (60 μg/L) and sodium pentachlorophenate (Na-PCP) (0, 300, 800, 1,000 and 1,200 μg/L) and atrazine (40 and 100 μg/L) with Na-PCP (700 and 1,200 μg/L) on *A. braunii* populations were additive over a wide range of concentrations. Similar results of atrazine (10 and 100 μg/L) and Na-PCP (300 and 1,200 μg/L) were obtained with C. *vulgaris.* In mixed algal cultures tested with atrazine (40 and 100 μg/L), cell numbers of *A*. *braunii* were reduced 50 and 80 percent, respectively, which was not significantly different than effects when tested alone. In the same mixed culture test, atrazine inhibited growth of C. *vulgaris* by 79 and 85 percent, respectively, which showed a significant growth inhibition only at the lower test concentration (40 μg/L). The authors concluded that the high atrazine concentration (100 μg/L) did not alter the established population relationship between the two algal species, but at the lower concentration (40 μg/L), *A*. *braunii* increased the susceptibility of *C*. *vulgaris* to atrazine. When mixed cultures of algae were treated with both atrazine (60 μg/L) and Na-PCP (300, 800, 1,000 and 1,200 μg/L), chemical antagonism was observed. The addition of the bacterium, *C*. *violaceum*, to the microcosm, had no effect on the level of antagonism for *A*. *braunii*. *C*. *violaceum* modified the antagonism of atrazine toxicity to *C*. *vulgaris* by about 40 percent, but the antagonistic effect was not eliminated. The net atrazine toxicity decreased as the Na-PCP concentration increased. The authors found no reason for the modification of atrazine effects by *C*. *violaceum*.

Carder and Hoagland (1998) reported that pesticide interactions of atrazine (0, 12 and 150 μg/L) and alachlor (0, 5, 90 μg/L) on benthic algal communities in artificial recirculating streams showed significant interaction (i.e., antagonism) only in the first week in the combination of high alachlor and low atrazine test concentrations. The authors concluded that the interaction is most likely anomalous and the lack of significant synergistic effects may be attributed to different modes of action.

2. Aquatic Animals

A number of authors have reported synergistic effects of atrazine with the aquatic animals with one or more of the following pesticides: (i.e., alachlor, chlorpyrifos, DDT, malathion, methyl parathion, parathion and trichlorfon).

Liang and Lichtenstein (1975) also found atrazine synergism between soil residues of both DDT and parathion using fruit flies, *Drosophila melanogaster* and measured lethal effects versus the age of the pesticide residues in soil. Ten grams of Plainfield sand (1.2 % organic matter) or Plano silt loam (4.7% organic matter) was mixed with parathion (2.3 μg/10 g of soil = 0.23 ppm) or DDT (30 μg/10 g of soil = 3 ppm), then was mixed with 10 g of the same soil type, which contained increasing atrazine levels (40 to 1000 μg/10 g of soil = 4 to 100 ppm) or controls. Fifty fruit flies were placed in 120 ml test jars for 24 hours with the 10-g portions of air-dried soil untreated or treated with atrazine, parathion, DDT or combinations thereof. The resulting 24-hour fruit fly LD_{50} values for constant soil levels of parathion (2.3 ppm) and DDT (3.0 ppm) were as follows: parathion (6.2 ppm atrazine in sand and 92 ppm in loam) and DDT (8.5 ppm atrazine in sand and 68 ppm in loam). Synergistic effects were apparent in all test combinations of soil and pesticides yielding a dose-response effect on fly mortality with increasing atrazine soil concentrations. Fruit fly mortality levels with both parathion and DDT in soils also clearly indicate a strong reduction in toxicity with the silt loam soil with a higher percentage of organic matter (4.7%) compared to sandy soil (1.2%).

Additional loam soil toxicity tests were conducted daily for 4 days, with aged-atrazine soil with an initial 50 ppm aged in the dark at 22°C and both fresh and aging-parathion soil levels (0.35 ppm). In the test with fresh parathion soils and aged-atrazine soils, toxicity to fruit flies decreased linearly from 95% mortality on Day 0 to 43.3% over four days. By the fourth day, atrazine levels had declined to 19 ppm, which was barely enough to synergize parathion in loam soils. In another toxicity test, parathion-treated soils were aged under the same conditions as above and added it daily to the initial 10 g of atrazine-treated soil (50 ppm). In this test, the toxicity to fruit flies decreased logarithmically from about 68% on Day 0 to 10% mortality on Day 4. The measured concentrations of aging parathion in the silt loam soil decreased at a rate paralleling the logarithmic toxicity curve. The final parathion level on Day 4 was 0.24 ppm.

Liang and Lichtenstein (1975) found atrazine to be synergistic with parathion in 24-hour aquatic tests with third-instar mosquito larvae, *Aeddes aegypti* and also assessed the effects of sand and loam soils on their individual and combined toxicity in 20 ml of pesticide-treated water. Atrazine at 10,000 μg/L showed no toxicity to the mosquito larvae; alone, parathion (15

μg/L) killed 20 $\pm$ 7 percent of the larvae; and at these concentrations, the combination of the two pesticides produced significantly ($p = 0.01$) higher mortality (73 $\pm$ 18 %). Addition of 5 g of Plainfield sand (1.2% organic matter) with 15 μg/L parathion reduced the toxicity of parathion from 20 $\pm$ 7% to 18 $\pm$4%, but when sand was mixed into the water, mortality drop to 5%. Plano silt loam soil (4.7% organic matter) without mixing reduced parathion toxicity from 20 $\pm$ 7% to 5 $\pm$ 4% and when the loam soil was mixed into the water, no mosquito larvae died. When these two soils were added to the same combination of atrazine and parathion, sand reduced the mortality from 73 $\pm$ 14% to 71 $\pm$ 14% (unmixed) and to 18 $\pm$ 4 % when mixed into the water; loam soil reduced the mortality from 73% to 64 $\pm$ 4% (unmixed) and to no mortality with mixing. The combination of atrazine and parathion was significantly ($p = 0.01$) more toxic than the toxicity of parathion or atrazine alone.

The above toxicity test method was repeated using 1 and 5 grams of sand or silt loam to measure the effect of different amounts of soil on toxicity following 24-hour exposures. Atrazine (10 ppm) produced no mortality in 24 hours to mosquito larvae. Parathion (0.015 ppm) produced 24 $\pm$ 7% mortality (no soil), 16 $\pm$ 7% (1g of sand), 2 $\pm$ 2% (5 g of sand), 7 $\pm$ 0% (1 g of loam soil) and 0% (5 g of loam soil). The combination of atrazine (10 ppm) and parathion (0.015 ppm) showed synergistic effects on mosquito larvae mortality: 62 $\pm$ 8% (no soil), 42 $\pm$ 10% (1 g of sand), 2 $\pm$ 2% (5 g of sand), 22 $\pm$ 4% (1 g of loam soil) and 0% (5 g of loam soil). These test format was repeated using higher pesticide concentrations and again the mortality levels were increased with a mixture of atrazine (20 ppm) and parathion (0.30), but the synergistic increase was much lower than in the previous test. The 24-hour results indicated that atrazine alone was not toxic to mosquito larvae; 0.30 ppm parathion (93 $\pm$ 6% mortality with on soil), 62 $\pm$ 8% with 5 g of sand and no mortality with silt loam soil. The mixture of 20 ppm atrazine and 0.30 ppm parathion produced 98 $\pm$ 4% mortality with no soil, 76 $\pm$ 4% dead when shaken with 5 g of sand, and 38 $\pm$ 10% lethality when shaken with 5 g of silt loam soil. These studies demonstrate that atrazine is synergistic with parathion and, like single toxicants, organic matter in soils and sediments will modify toxicity of pesticide mixtures, especially if the organic matter is suspended in the water. While this particular study has limited value for risk assessment, because the atrazine levels (10 and 20 ppm) exceed the normal environmental range of atrazine exposures, the study suggests that synergism of atrazine and parathion may occur at lower concentrations, possibly in the range of environment levels of atrazine.

Pape-Lindstrom and Lydy (1997) tested atrazine with 6 pesticides for chemical interactions using 4th instar midges (*Chironomus tentans*). The 96-hour test results for the pesticide mixtures indicated that atrazine was synergistic with the phosphonate insecticide, trichlorfon, (0.26 toxic units) and 3 phosphorothioate insecticides (i.e., malathion (0.36 TU), chlorpyrifos (0.58 TU) and methyl parathion (0.59 TU). The atrazine-mevinophos (a phosphate) mixture was less than additive (1.34 TU), while methoxychlor, a organochlorine insecticide mixture was also less than additive (1.67 TU). The results from these tests are questionable, since DMSO was used as a solvent with atrazine. These tests were repeated by Belden and Lydy (2000) without DMSO and with lower atrazine concentrations (0, 10, 40, 80, and 200 μg/L). Acute 96-hour tests with *Chironomus tentans* were conducted with each pesticide and EC_1, EC_5, EC_{15} and EC_{50} values were determined based on inability of the midge to swim when prodded with

forceps. Chemical interactions were tested at each of these EC levels with atrazine levels of 0, 10, 40, 80 and 200 μg/L using 5 replicates of 10 midges each. Atrazine increased the toxicity of chlorpyrifos, diazinon and parathion, but not malathion. The authors concluded that "Interaction terms were not significant for atrazine + methyl parathion and atrazine + diazinon; however, a significant interaction was found for the atrazine + chlorpyrifos test (p = 0.002, df - 12, F = 2.94)." Synergistic ratios were reported as follows: chlorpyrifos, 1.83 at 40 μg/L and 4.00 at 200 μg/L atrazine; at 200 μg/L diazinon the SR was 2.71 and for methyl parathion, the SR was 1.94. The variety of chemical interactions produced by atrazine mixtures indicates that the effect of atrazine on an organism is dependent on the species, cocontaminant, and the concentration of atrazine. Additional tests with 200 μg/L atrazine and chlorpyrifos showed that atrazine increased the uptake of chlorpyrifos by 42 percent, and that the atrazine induction of cytochrome-P450 increased the formation of the O-analog which increased the toxicity of chlorpyrifos at enviromentally relevant concentrations.

Howe *et al*. 1998 reported synergism between atrazine and alachlor, a herbicide, in tests with young rainbow trout, channel catfish and early and late tadpole stages of the northern frog and the American toad. The results are presented in the table below. (MRID # 45202910).

Species (stage)	Time (hour)	Atrazine LC50 (95% CI) mg/L	Alachlor LC50 (95% CI) mg/L	Atrazine-Alachlor LC50[a] (95% CI) mg/L	Additive Index[b] (95% CI)
Rainbow trout	24	31.6 (28.2 - 35.4)	10.6 (9.5 - 11.7)	9.5 (8.3 - 10.9)	-0.20 (-0.53-0.059)
(0.8-1.0-gram juveniles)	96	20.5 (18.3 - 22.9)	9.1 (9.0 - 9.2)	6.5 (5.7 - 7.7)	-0.03 (-0.28-0.15)
Channel catfish	24	51.3 (44.6 - 59.0)	23.8 (22.7 - 25.0)	11.1 (9.6 - 12.4)	0.29 (0.067-0.55)[c]
(0.9-1.1-gram juveniles)	96	23.8 (22.3 - 25.5)	16.7 (15.1 - 18.4)	7.5 (5.3 - 8.4)	0.31 (0.072-0.57)[c]
Northern leopard frog	24	69.7 (63.1 - 77.2)	14.9 (13.3 - 16.6)	12.1 (11.0 - 12.9)	0.015 (-0.17-0.24)
(0.7-0.9-gr early larvae)	96	47.6 (41.4 - 54.8)	11.5 (10.1 - 13.2)	6.5 (5.7 - 7.7)	0.43 (0.054-0.87)[c]
Northern leopard frog	24	45.3 (42.3 - 48.5)	7.3 (6.6 - 8.0)	5.9 (5.5 - 6.4)	0.07 (-0.12-0.25)
(1.4-1.9-gr late larvae)	96	14.5 (11.9 - 17.5)	3.5 (3.1 - 3.8)	2.1 (2.0 - 2.3)	0.34 (0.069-0.56)[c]
American Toad	24	66.4 (58.9 - 74.9)	5.7 (4.7 - 5.8)	4.4 (4.2 - 4.6)	0.19 (-0.057-0.28)
(0.1-0.2-gr early larvae)	96	26.5 (23.0 - 30.5)	3.9 (3.7 - 4.2)	1.8 (1.7 - 1.9)	0.89 (0.68 - 1.2)[c]
American Toad	24	15.8 (13.5 - 18.4)	4.3 (3.8 - 4.8)	2.9 (2.6 - 3.3)	0.17 (0.11 - 0.46)[c]
(0.4-0.5-gr late larvae)	96	10.7 (9.2 - 12.5)	3.3 (2.8 - 3.6)	1.5 (1.4 - 1.6)	0.68 (0.34 - 1.0)[c]

[a] 50:50 mixture of atrazine 4L (40.8% ai.) and alachlor EC (43.0% ai.).
[b] An additive index greater than zero indicates greater than additive toxicity.
[c] Significant chemical synergy interaction between atrazine and alachlor.

h. US EPA, Office of Water, Water Quality Criteria

The Office of Water sets ambient aquatic life water quality criteria to be used under two sections of the Clean Water Act, section 304(a)(1) and section 303(c)(2). In section 304, the term represents a non-regulatory, scientific assessment of ecological effects. If water quality criteria associated with specific stream uses are adopted by a state as water quality standards under section 303, they become enforceable maximum acceptable pollutant concentrations in ambient waters within that state. Water quality criteria adopted in state water quality standards could have the same numerical values as criteria developed under section 304. However, in

many situations states might want to adjust water quality criteria developed under section 304 to reflect local environmental conditions and human exposure patterns. Alternatively, states may use different data and assumptions than EPA in deriving numeric criteria that are scientifically defensible and protective of designated uses. It is not until their adoption as a part state water quality standards that criteria become regulatory.

The ambient aquatic life water quality criteria for atrazine is currently under review. An atrazine draft dated, 6/12/00, has been published for public comment. The proposed water quality criteria values for atrazine are presented in the table below.

OW, Water Quality Criteria for Atrazine (μg/L)			
	Final Acute Value	Fish Chronic Value	Invertebrate Chronic Value
Freshwater Criteria	657.3	11.56	85.11
Saltwater Criteria	641.5	11.28	83.06

h. US EPA, OPP, Terrestrial and Aquatic Most Sensitive Toxicity Values

The most sensitive terrestrial and aquatic toxicity values used to assess risks from pesticide use are presented in the table below.

OPP, Terrestrial and Aquatic Toxicity Values for Atrazine			
	Acute Value	Dietary Value	Chronic Value
Terrestrial Organisms:	(mg/kg)	(ppm)	(ppm)
Birds	940	> 5,000 (30 % dead)	< 75
Mammals	224	—	10
Freshwater Organisms:	(μg/L)		(μg/L)
Fish	4,500	—	65
Invertebrates	720	—	60
Saltwater Organisms:	(μg/L)		(μg/L)
Fish	8,500	—	1,900
Invertebrates	88	—	80

Terrestrial Plants:	(lbs ai/A)		
Seedling Emergence:			
Dicot	0.003	—	—
Monocot	0.004	—	—
Vegetative Vigor;			
Dicot	0.008	—	—
Monocot	0.61	—	—
Aquatic Plants:	(μg/L)		(μg/L)
Freshwater Plants:			
Algae	< 1		25
Vascular Plants	2		2
Saltwater Plants:			
Algae	10		22
Vascular Plants	< 4		8

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Appendix XIII. Endangered Species Concerns

Atrazine poses a risk to a number of sensitive crop species from spray drift and spray drift/runoff assessments.

The Agency has developed a program (the "Endangered Species Protection Program") to identify pesticides whose use may cause adverse impacts on endangered and threatened species, and to implement mitigation measures that will eliminate the adverse impacts. At present, the program is being implemented on an interim basis as described in a Federal Register notice (54 FR 27984-28008, July 3, 1989), and is providing information to pesticide users to help them protect these species on a voluntary basis. As currently planned, the final program will call for label modifications referring to required limitations on pesticide uses, typically as depicted in county-specific bulletins or by other site-specific mechanisms as specified by state partners. A final program, which may be altered from the interim program, will be described in a future Federal Register notice. The Agency is not imposing label modifications at this time through the RED. Rather, any requirements for product use modifications will occur in the future under the Endangered Species Protection Program.

Levels of Concern for Endangered species are exceeded for terrestrial and aquatic plants. Risk quotients exceed the levels of concern for endangered terrestrial plant species from spray drift and from runoff for both terrestrial and semi-aquatic plants. The level of concern for endangered plant species has been exceeded for atrazine uses on corn, sorghum and sugarcane for both maximum and typical use rates.

In general, risks to birds, mammals, beneficial insects, fish and aquatic invertebrates are not anticipated from direct effects of atrazine use and the levels of concern are not exceeded. However, atrazine use could have important effects on terrestrial and aquatic plants in areas adjacent to treated fields that would have indirect effects on these animals from the loss of food sources and the loss of vegetative habitat for cover, reproduction and the survival of offspring. Loss of food and vegetative habitat could force the animals to leave the affected areas and seek another acceptable habitats. Limits on acceptable habitats would increase stress on species competing for limited resources and may affect the ability to successfully reproduce and feed the young.

Kettle et al. (1987) demonstrated severe vegetative habitat and indirect effects from 20 μg/L of atrazine in artificial Kansas ponds. Atrazine effects in the ponds included 60 to 90 percent reduction in vascular pond vegetation and the loss of three plant species, significant reductions in aquatic macro-invertebrate populations, a significant reduction in food consumption by adult bluegills, and a 96 percent reduction in the number of young bluegill. It is likely that reductions in the number of macro-invertebrates are due to the loss of vegetative cover to avoid predators and that bluegill young were eaten due to limited vegetative cover and the reduced availability of food (i.e., aquatic invertebrates) for adult fish species. Atrazine levels of 20 μg/L in streams and rivers are not rare occurrences and these concentrations may adversely affect aquatic vegetation, such that the loss of the vegetative habitat could affect populations of endangered aquatic invertebrates, especially crustaceans and the recruitment of young endangered fish species.

It is uncertain what effects atrazine use on crops and forests might have on vegetation in field margins and riparian areas that are necessary and important habitats for movement, cover, feeding, and reproduction for terrestrial endangered animal species, including endangered insects, amphibians, fish, birds and mammals. Riparian areas along aquatic habitats moderate water temperature and may impact the stream water quality by reducing spray drift and runoff to aquatic areas. Herbicide effects on vegetation losses in these areas may have significant effects of the suitability of these areas as habitats and food sources for endangered animal species. Reductions in acceptable habitat and limited resources are the major factors affecting many endangered and threatened species, whether they be plants, insects, clams and mussels, aquatic invertebrates, fish, birds or mammals.

Uncertainty also exists on the extent of atrazine effects on the homing and reproduction in endangered salmon and other anadromous fish species. The study of olfactory function in mature Atlantic salmon parr and the effect of atrazine in the range of 0.5 μg/L for sensing female hormones in urine and behavior to ground salmon skin is disconcerting. If this effect has a significant effect on salmon reproduction at such a low atrazine concentration, existing atrazine concentrations in many streams and rivers are likely to exceed this level for prolong periods, especially in the late spring and early summer following atrazine applications at a time when salmon are returning from the ocean to spawn. It is unclear from the results of the test by Moore and Waring (1998) whether the effect on olfactory function is manifested in mature adult salmon and what affect it might have on reproduction and recruitment. The same test has been conducted with diazinon (0.03μg/L) and carbofuran with similar results. Diazinon effects on olfactory function in homing has been tested in Washington State and showed fewer returns than for controls, but the control return rate was low, only 30 percent. This effect on migratory salmon is a concern should atrazine be found to also have an effect on homing in mature, migrating salmon. These data are preliminary and additional studies are necessary to determine if there are adverse atrazine effects and on adult salmon homing and adult male milt production responses to female hormones in ovulating female urine. And whether that effect has a significant on reproduction and recruitment.

As a member of the Endangered Species Task Force, the registrant is responsible for determining the distribution and the proximity of endangered and threatened species to crops with registered uses of atrazine. Risks to endangered and threatened plants for both terrestrial and aquatic species need to be assessed. Due to indirect effects of atrazine on vegetative effects, the registrant needs to consider risks to endangered and threatened species in the following categories: mammals, birds, insects, amphibians, aquatic invertebrates and fish.

MEMORANDUM April 3, 2002

SUBJECT: EFB/FEAD Endangered Species Review for Atrazine RED

FROM: Ann Stavola, Biologist
Environmental Field Branch
Field and External Affairs Division, 7506c

TO: William Rabert, Biologist
ERB III
Environmental Fate and Effects Division, 7507c

Atrazine was included in the formal Section 7 consultations with the US Fish and Wildlife Service (USFWS) for the rangeland/pastureland and the forest cluster reviews in 1984. The Biological Opinions for both reviews stated that these uses of atrazine would jeopardize the continued existence of over 60 species of plants associated with rangeland and ten species of plants associated with forests. Atrazine was also included in the sorghum cluster review in 1983, and the Biological Opinion found possible jeopardy to several species of fish plus one insect (loss of habitat) and one plant species.

Atrazine was also included in the reinitiated Biological Opinion of 1989 from the USFWS. In this opinion, the Service found jeopardy to nine species of freshwater fish, two freshwater crustaceans, four amphibians and twelve species of plants for its uses on field crops, rangeland and forests. Reasonable and Prudent Alternatives were given for each jeopardized species. Reasonable and Prudent Measures were also given for 43 non-jeopardized species to minimize incidental take of these species. These consultations and the findings expressed in the Opinions, however, are based on old labels and application methods, less refined risk assessment procedures and an older approach to consultation which is currently being revised through interagency collaboration.

When the regulatory changes recommended in this IRED are implemented and the ecological effects and environmental fate data are submitted and accepted by the Agency, the Reasonable and Prudent Alternatives and Reasonable and Prudent Measures in the Biological Opinion(s) may need to be reassessed and modified based on the new information.

The Agency is currently engaged in a Proactive Conservation Review with FWS and the National Marine Fisheries Service under section 7(a)(1) of the Endangered Species Act. The objective of this review is to clarify and develop consistent processes for endangered species risk assessments and consultations. Subsequent to the completion of this process, the Agency will reassess the potential effects of atrazine use to federally listed threatened and endangered species. At that time the Agency will also consider any regulatory changes recommended in the IRED that are being implemented. Until such time as this analysis is completed, the overall environmental effects mitigation strategy articulated in this document and any County Specific Pamphlets described in Section IV which address atrazine, will serve as interim protection

measures to reduce the likelihood that endangered and threatened species may be exposed to atrazine at levels of concern.

The Agency has developed the Endangered Species Protection Program to identify pesticides whose use may cause adverse impacts on endangered and threatened species, and to implement mitigation measures that address these impacts. The Endangered Species Act requires federal agencies to ensure that their actions are not likely to jeopardize listed species or adversely modify designated critical habitat. To analyze the potential of registered pesticide uses to affect any particular species, EPA puts basic toxicity and exposure data developed for REDs into context for individual listed species and their locations by evaluating important ecological parameters, pesticide use information, the geographic relationship between specific pesticide uses and species locations, and biological requirements and behavioral aspects of the particular species. This analysis will take into consideration any regulatory changes recommended in this RED that are being implemented at this time. A determination that there is a likelihood of potential impact to a listed species may result in limitations on use of the pesticide, other measures to mitigate any potential impact, or consultations with the Fish and Wildlife Service and/or the National Marine Fisheries Service as necessary.

The Endangered Species Protection Program as described in a Federal Register notice (54 FR 27984-28008, July 3, 1989) is currently being implemented on an interim basis. As part of the interim program, the Agency has developed County Specific Pamphlets that articulate many of the specific measures outlined in the Biological Opinions issued to date. The Pamphlets are available for voluntary use by pesticide applicators on EPA's website at www.epa.gov/espp. A final Endangered Species Protection Program, which may be altered from the interim program, is scheduled to be proposed for public comment in the Federal Register in the first half of 2002.

If there are any questions, please contact me at 305-5354.

Case No: 0???
Chemical No: 080803

ENVIRONMENTAL FATE
DATA REQUIREMENTS FOR
ATRAZINE

Data Requirement		Use Pattern[1]	Does EPA Have Data To Satisfy This Requirement? (Yes, No, or Partially)	Bibliographic Citation	Must Additional Data Be Submitted under FIFRA 3(c)(2)(B)?
§158.290 ENVIRONMENTAL FATE					
Degradation Studies-Lab:					
161-1	Hydrolysis	ABCJK	yes	40431319	no
161-2	Photodegradation In Water	ABCJK	yes	42089904	no
161-3	Photodegradation On Soil	ABCJK	yes	40431320,42089905	no
161-4	Photodegradation In Air				no
Metabolism Studies-Lab:					
162-1	Aerobic Soil	ABCJK	yes	42089906	no
162-2	Anaerobic Soil	ABCJK	yes	42089906	no
162-3	Anaerobic Aquatic	ABCJK	yes	40431323	no
162-4	Aerobic Aquatic	ABCJK	no		yes
Mobility Studies:					
163-1	Leaching- Adsorption/Desorp.	ABCJK	yes	40331324,40431327,40431325 40431328,40431326	no
163-2	Volatility (Lab)	ABCJK	no		yes
163-3	Volatility (Field)	ABCJK	no		???
Dissipation Studies-Field:					
164-1	Soil Dissipation	ABCJK	yes	42165504,42165505,40431336, 42165506,40431337,421655507	no
164-2	Aquatic (Sediment)	ABCJK	no		yes
164-3	Forestry	ABCJK	yes	40431340,42041405	no
164-5	Soil, Long-term	ABCJK	yes	40431339, 42089911,40431337	no

				42089912,40431338,42089909 40431336,42089910	

Accumulation Studies:

165-3	Irrigated Crops				
165-4	In Fish	ABCJK	yes	40431344	no
165-5	In Aquatic Non-Target Org.	ABCJK	no		yes

Ground Water Studies:

166-1	Ground Water Small Prosp.
166-2	Ground Water Small Retro.

Surface Water Studies:

167-1	Field Runoff
167-2	Surface Water Monitoring

§158.440 Spray Drift:

201-1	Droplet Size Spectrum	ABCJK	no		yes	
202-1	Drift Field Evaluation	ABCJK	no			yes

[1] Use Patterns: A=Terrestrial Food Crop; B=Terrestrial Feed Crop; C=Terrestrial Non-Food Crop; D=Aquatic Food Crop; E=Aquatic Non-Food Outdoor; F=Aquatic Non-Food Industrial; G=Aquatic Non-food Residential; H=Greenhouse Food Crop; I=Greenhouse Non-Food Crop; J=Forestry; K=Outdoor Recreation; L=Indoor Food; M=Indoor Non-Food; N=Indoor Medical; O=Indoor Residential; Z=Use Group for Site 00000

Date: November 2000
Case No:
Chemical No: 080803

PHASE IV
DATA REQUIREMENTS FOR
ECOLOGICAL EFFECTS BRANCH

Data Requirements	Composition[1]	Use Pattern[2]	Does EPA Have Data To Satisfy This Requirement? (Yes, No)	Bibliographic Citation (MRID)	Must Additional Data Be Submitted under FIFRA3(c)(2)(B)?
6 Basic Studies in Bold					
71-1(a) Acute Avian Oral, Quail/Duck Northern Quail to be tested	TGAI 3 Major Degradates	ABCJK ABCJK	yes no	00024721	no yes
71-1(b) Acute Avian Oral, Quail/Duck	(TEP)				no
71-2(a) Acute Avian Diet, Quail	TGAI Degradates	ABCJK ABCJK	yes no	00022923	no reserved
71-2(b) Acute Avian Diet, Duck	TGAI	ABCJK	yes	00022923	no
71-3 Wild Mammal Toxicity					no
71-4(a) Avian Reproduction Quail	TGAI Degradates	ABCJK ABCJK	yes no	42547102	no reserved
71-4(b) Avian Reproduction Duck	TGAI Degradates	ABCJK ABCJK	yes no	42547101	no reserved
71-5(a) Simulated Terrestrial Field Study					no
71-5(b) Actual Terrestrial Field Study					no
72-1(a) Acute Fish Toxicity Bluegill	TGAI Major Degradate	ABCJK ABCJK	yes no	00024717	no yes
72-1(b) Acute Fish Toxicity Bluegill	(TEP)				
72-1© Acute Fish Toxicity Rainbow Trout	TGAI Major Degradate	ABCJK ABCJK	yes no	00024716	no yes
72-1(d) Acute Fish Toxicity Rainbow Trout	(TEP)				

* In Bibliographic Citation column indicates study may be upgradeable

Date: November 2000
Case No:
Chemical No: 080803

PHASE IV
DATA REQUIREMENTS FOR
ECOLOGICAL EFFECTS BRANCH

Data Requirements	Composition[1]	Use Pattern[2]	Does EPA Have Data To Satisfy This Requirement? (Yes, No)	Bibliographic Citation (MRID)	Must Additional Data Be Submitted under FIFRA3(c)(2)(B)?
72-2(a) Acute Aquatic Invertebrate Toxicity	TGAI Major Degradate	ABCJK ABCJK	yes no	00024377	no yes
72-2(b) Acute Aquatic Invertebrate Toxicity	(TEP)				
72-3(a) Acute Estu/Mari Tox Fish	TGAI Major Degradate	ABCJK ABCJK	yes no	43344901	no yes
72-3(b) Acute Estu/Mari Tox Mollusk	TGAI Major Degradate	ABCJK ABCJK	no no		yes yes
72-3© Acute Estu.Mari Tox Shrimp	TGAI Major Degradate	ABCJK ABCJK	yes no	43344902	no yes
72-3(d) Acute Estu/Mari Tox Fish	(TEP)				
72-3(e) Acute Estu/Mari Tox Mollusk	(TEP)				
72-3(f) Acute Estu/Mari Tox Shrimp	(TEP)				
72-4(a) Early Life-Stage Fish (Freshwater)	TGAI Major Degradate	ABCJK ABCJK	no no	45208304	no reserved
72-4(a) Early Life-Stage Fish (Marine)	TGAI	ABCJK	no	45202920 *	yes
72-4(b) Life-Cycle Aquatic Invertebrate	TGAI Major Degradate	ABCJK ABCJK	yes no	00024377	no reserved
72-4(b) Life-Cycle Marine Invertebrate	TGAI Major Degradate	ABCJK ABCJK	no no	45202920 *	yes reserved
72-5 Life-Cycle Fish	TGAI Major Degradate	ABCJK ABCJK	yes no	00024377	no reserved
72-6 Aquatic Org. Accumulation					
72-7(a) Simulated Aquatic Field Study					
72-7(b) Actual Aquatic Field Study					

* In Bibliographic Citation column indicates study may be upgradeable

Date: November 2000
Case No:
Chemical No: 080803

PHASE IV
DATA REQUIREMENTS FOR
ECOLOGICAL EFFECTS BRANCH

Data Requirements	Composition[1]	Use Pattern[2]	Does EPA Have Data To Satisfy This Requirement? (Yes, No)	Bibliographic Citation (MRID)	Must Additional Data Be Submitted under FIFRA3(c)(2)(B)?
122-1(a) Seed Germ./Seedling Emerg.	TEP				
122-1(b) Vegetative Vigor	TEP				
122-2 Aquatic Plant Growth					
123-1(a) Seed Germ./Seedling Emerg.	TEP	ABCJK	yes	42041403	no
123-1(b) Vegetative Vigor	TEP	ABCJK	yes	42041402	no
123-2 Aquatic Plant Growth	TGAI	ABCJK	yes	41065203a 41065203b 43074801 43074802 43074803	no
124-1 Terrestrial Field Study					
124-2 Aquatic Field Study					
141-1 Honey Bee Acute Contact	TGAI	ABCJK	yes	00036935	no
141-2 Honey Bee Residue on Foliage	TEP		no		no
141-5 Field Test for Pollinators	TEP		no		no

[1] Composition: TGAI=Technical grade of the active ingredient; PAIRA=Pure active ingredient, radiolabeled; TEP=Typical end-use product

[2] Use Patterns: A=Terrestrial Food Crop; B=Terrestrial Feed Crop; C=Terrestrial Non-Food Crop; D=Aquatic Food Crop; E=Aquatic Non-Food Outdoor; F=Aquatic Non-Food Industrial; G=Aquatic Non-food Residential; H=Greenhouse Food Crop; I=Greenhouse Non-Food Crop; J=Forestry; K=Outdoor Recreation; L=Indoor Food; M=Indoor Non-Food; N=Indoor Medical; O=Indoor Residential; Z=Use Group for Site 00000

* In Bibliographic Citation column indicates study may be upgradeable